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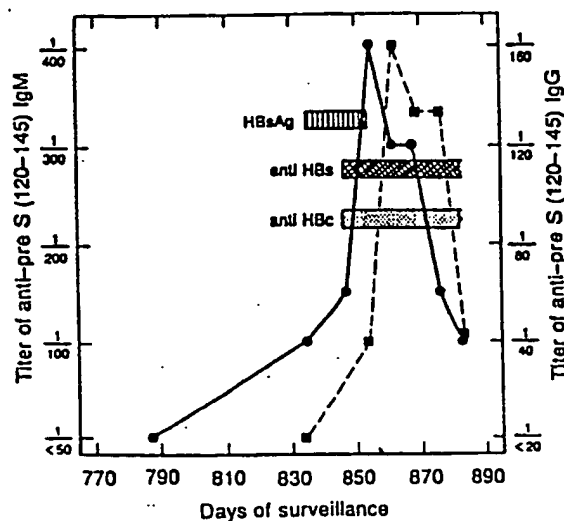
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Pre-S gene coded peptide hepatitis B immunogens, vaccines, diagnostics, and synthetic lipid vesicle carriers.

A hepatitis B vaccine containing a peptide with an amino acid chain of at least six consecutive amino acids within the pre-S gene coded region of the envelope of hepatitis B virus. The vaccine being free of an amino acid sequence corresponding to the naturally occurring envelope proteins of hepatitis B virus and a physiologically acceptable diluent. The peptide being free or linked to a carrier. The carrier being a conventional carrier or a novel carrier including a lipid vesicle stabilized by cross-linking and having covalently bonded active sites on the outer surface thereon. Such novel carrier being useful not only to link the novel peptide containing an amino acid chain with amino acids within the pre-S gene coded region of the surface antigen of hepatitis B virus, but can also be used to bind synthetic peptide analogues of other viral proteins, as well as bacterial, allergen and parasitic proteins of man and animals. The peptides of the invention can be utilized in diagnostics for the detection of antigens and antibodies.



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BACKGROUND OF THE INVENTION

The present invention concerns pre-S gene coded hepatitis B immunogens, vaccines and diagnostics. More especially, this invention concerns novel pre-S gene coded peptides and novel carriers, particularly carriers for pre-S gene coded peptides. Even more especially, the present invention relates to synthetic pre-S gene coded peptides covalently linked to lipid vesicle carriers.

There are approximately 600,000 persistent carriers of hepatitis B virus (HBV) in the United States; the estimated total number of carriers in the world is 200 million. A considerable portion of HBV carriers have chronic liver disease. The involvement of HBV in liver cancer has been demonstrated (W. Szmuness, Prog. Med. Virol. 24, 40 (1978) and R.P. Beasley, L.-Y. Hwang, C.-C. Ling, C.-S. Chien, Lancet Nov., 21, 1129 (1981)).

HBV infections thus represent a major public health problem worldwide. Already available vaccines (S. Krugman, in Viral Hepatitis: Laboratory and Clinical Science, F. Deinhardt, J. Deinhardt, Eds., Marcel Dekker, Inc., New York-Basel, 1983, pp. 257-263) produced from the serum of HBV carriers, because of limited resources and production costs involved, do not provide the appropriate

1 means to control and eradicate the disease worldwide. There  
2 is hope, however, that this may be accomplished by vaccination  
3 based on recombinant DNA technology and/or synthetic  
4 peptides.

5 The biology, structure and immunochemistry of HBV  
6 and the genetic organization of its DNA genome have been  
7 reviewed (B.S. Blumberg, Science, 197 17, (1977)). The  
8 cloning and sequencing of the genome of several hepatitis  
9 virus (HBV) isolates led to the elucidation of the genetic  
10 structure of the viral DNA (P. Tiollais, P. Charnay, G.N.  
11 Vyas, Science, 213, 406, (1981)).

12 The immunologic markers of HBV infection include  
13 the surface antigen (HBsAg), the core antigen (HBcAg), the  
14 "e" antigen (HBeAg) and their respective antibodies.  
15 Antibodies against HBsAg are protective against HBV  
16 infection.

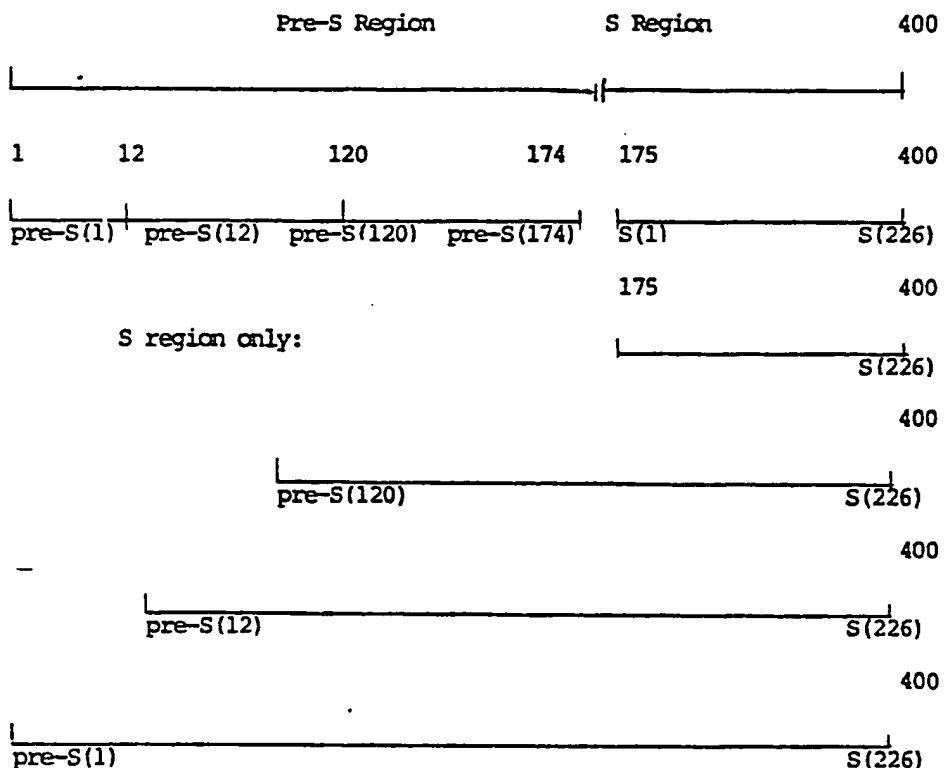
17 Several antigenic subtypes of HBV and of subvira  
18 approximately 22 nm diameter particles (hepatitis B surface  
19 antigen; HBsAg) have been recognized (G. Le Bouvier, A.  
20 Williams, Am. J. Med. Sci., 270, 165 (1975)). All of these  
21 subtypes (for example, ayw, adyw, adw2, adw and adr) share  
22 common (group-specific) envelope epitopes, the immune  
23 response against which appears sufficient for protection  
24 against infection by any of the virus subtypes (W. Szmunes  
25 C.E. Stevens, E.J. Harley, E.A. Zang, H.J. Alter, P.E.  
26 Taylor, A. DeVera, G.T.S. Chen, A. Kellner, et al., N. Eng  
27 J. Med., 307, 1481, (1982)).

28 The physical structure and proposed genetic  
29 organization of the HBV genome are described by Tiollais et  
30

al, 1981, supra at p. 408-409. There are two DNA strands, namely the long (L) strand and the short (S) strand. The L strand transcript has four open reading frame regions which are termed (S + pre-S), C, P and X.

The open reading frame region (S + pre-S) corresponds to the envelope (env) gene of HBV DNA and codes for a family of proteins found in the HBV envelope and in virus related particles.

A schematic representation of the potential translation products of the env gene(s) of HBV DNA is as follows:



The numbers in the above schematic refers to amino acids (AA). A translation initiation site at Met 1 exists

1 for the adw<sub>2</sub> and adr subtypes only. The first amino acid  
2 for the other subtypes correspond to position pre-S 12.

3 Hereinafter, amino acid sequences corresponding to  
4 the pre-S region (env 1 to 174) are designated with the  
5 prefix "pre-S" and amino acid sequences corresponding to the  
6 S region (env 175 to 400) are designated by the prefix "S".  
7 In the env gene product representation, the S region spans  
8 amino acids 175 to 400 as compared to amino acids 1 to 226  
9 in the "S region only" representation.

10 In the above schematic, the pre-S region is  
11 defined by amino acid sequence positions pre-S 1 to amino  
12 acid sequence position pre-S 174. The S region is defined by  
13 sequence positions S 1 (amino acid 175 of the open reading  
14 frame and adjacent to pre-S 174) to sequence position S 266  
15 (amino acid 400 of the open reading frame). The s-gene  
16 product (S-protein) consists of this 226 amino acid  
17 sequence.

18 The epitope(s) essential for eliciting  
19 virus-neutralizing antibodies have not yet been  
20 unambiguously defined. It has been reported that the  
21 group-specificity is represented by a complex of  
22 determinants located on each of the two major approximately  
23 22 and approximately 26 kilodalton constituent proteins (P22  
24 and P26) of the virus envelope and of the hepatitis B  
25 surface antigen (HBsAg). See J.W.-K. Shih, J.L. Gerin, J.  
26 Immunol., 115, 634, (1975); J.W.-K. Shih, P.L. Tan, J.L.  
27 Gerin, J. Immunol., 120, 520, (1978); S. Mishiro, M. Imai,  
28 K. Takahashi, A. Machida, T. Gotanda, Y. Miyakawa, M.

1 Mayumi, J. Immunol., 124, 1589, (1980); and G.R. Dreesman,  
2 R. Chairez, M. Suarez., F.B. Hollinger, R.J. Courtney, J.L.  
3 Melnick, J. Virol., 16, 568, (1975).

4 These proteins have identical amino acid sequences  
5 coded for by the S-gene of HBV DNA (Tiollais et al, supra),  
6 but the larger protein also carries carbohydrate chains.  
7 Peptides corresponding to selected segments of the S-gene  
8 product were synthesized and shown to elicit antibodies to  
9 HBsAg (anti-HBs). However, immunization of chimpanzees with  
10 these peptides resulted in only partial protection against  
11 HBV infection (N. Williams, Nature, 306, 427, (1983)).

12 It has been reported recently that the minor  
13 glycoprotein components of HBsAg with  $M_r$  of approximately 33  
14 and approximately 36 kilodaltons (P33, P36) are coded for  
15 HBV DNA and contain the sequence of P22 (226 amino acids  
16 corresponding to the S region) and have 55 additional amino  
17 acids at the amino-terminal part which are coded by the  
18 pre-S region of the env gene(s) of HBV DNA. See W. Stibbe,  
19 W.H. Gerlich, Virology, 123, 436, (1982); M.A. Feitelson,  
20 P.L. Marion, W.S. Robinson, Virology, 130, 76, (1983); W.  
21 Stibbe, W.H. Gerlich, J. Virol., 46, 626, (1983); and A.  
22 Machida, S. Kishimoto, H. Ohnuma, H. Miyamoto, K. Baba, K.  
23 Oda, T. Nakamura, Y. Miyakawa, M. Mayumi, Gastroenterology,  
24 85, 268, (1983). Machida et al describe an amino acid  
25 sequence composition as a receptor for polymerized serum  
26 albumin.

27  
28 Heretofore, amino acid sequences coded for by the  
29 pre-S region of the hepatitis B virus DNA were virtually  
30

1 completely ignored for purposes of producing synthetic  
2 vaccines. The hepatitis B vaccine currently in use in the  
3 United States lacks the pre-S gene coded sequences (and  
4 therefore does not elicit antibodies to such sequences) and  
5 thus elicits an immune response to the HBV envelope which is  
6 incomplete as compared with that occurring during recovery  
7 from natural infection.

8 The generation of antibodies to proteins by  
9 immunization with short peptides having the amino acid  
10 sequence corresponding to the sequence of preselected  
11 protein fragments appears to be a frequent event (Nima,  
12 H.L., Houghten, R.A., Walker, L.E., Reisfeld, R.A., Wilson,  
13 I.A., Hogle, J.M. and Lerner, R.A., "Generation Of  
14 Protein-Reactive Antibodies By Short Peptides Is An Event Of  
15 High Frequency: Implications For The Structural Basis Of  
16 Immune Recognition", Proceedings of the National Academy of  
17 Sciences USA, 80, 4949-4953, (1983)). Nevertheless, the  
18 generation of antibodies which recognize the native protein  
19 may depend on the appropriate conformation of the synthetic  
20 peptide immunogen and on other factors not yet understood.  
21 See Pfaff, E., Mussgay, M., Böhm, H.O., Schulz, G.E. and  
22 Schaller, H., "Antibodies Against A Preselected Peptide  
23 Recognize And Neutralize Foot And Mouth Disease Virus", The  
24 EMBO Journal, 7, 869-874, (1982); Neurath, A.R., Kent,  
25 S.B.H. and Strick, N., "Specificity Of Antibodies Elicited  
26 By A Synthetic Peptide Having A Sequence In Common With A  
27  
28  
29  
30

1 Fragment Of A Virus Protein, The Hepatitis B Surface  
2 Antigen," Proceedings Of The National Academy Of Sciences  
3 USA, 79, 7871-7875, (1982); Ionescu-Matiu, I., Kennedy,  
4 R.C., Sparrow, J.T., Culwell, A.R., Sanchez, Y., Melnick,  
5 J.L. and Dreesman, G.R., "Epitopes Associated With A  
6 Synthetic Hepatitis B Surface Antigen Peptide", The Journal  
7 Of Immunology, 130, 1947-1952, (1983); and Kennedy, R.C.,  
8 Dreesman, G.R., Sparrow, J.T., Culwell, A.R., Sanchez, Y.,  
9 Ionescu-Matiu, I., Hollinger, F.B. and Melnick, J.L. (1983);  
10 "Inhibition Of A Common Human Anti-Hepatitis B Surface  
11 Antigen Idiotypic By A Cyclic Synthetic Peptide," Journal of  
12 Virology, 46, 653-655, (1983). For this reason, immunization  
13 with synthetic peptide analogues of various virus proteins  
14 has only rarely resulted in production of virus-neutralizing  
15 antisera comparable to those elicited by the viruses (virus  
16 proteins) themselves (Pfaff et al., 1982, supra). Thus, the  
17 preparation of synthetic immunogens optimally mimicking  
18 antigenic determinants on intact viruses remains a  
19 challenge.  
20

21 Replacement of commonly used protein carriers,  
22 namely keyhole limpet hemocyanin (KLH), albumin, etc., by  
23 synthetic carriers, represents part of such challenge.  
24 Although recent reports indicate that free synthetic  
25 peptides can be immunogenic, (Dreesman, G.R., Sanchez, Y.,  
26 Ionescu-Matiu, I., Sparrow, J.T., Six, H.R., Peterson, D.L.,  
27 Hollinger, F.B. and Melnick, J.L., "Antibody To Hepatitis B  
28  
29  
30



1 peptides can be immunogenic, (Dreesman, G.R., Sanchez, Y.,  
2 Ionescu-Matiu, I., Sparrow, J.T., Six, H.R., Peterson, D.L.,  
3 Hollinger, F.B. and Melnick, J.L., "Antibody To Hepatitis B  
4 Surface Antigen After A Single Inoculation Of Uncoupled  
5 Synthetic HBsAg Peptides" Nature, 295, 158-160, (1982), and  
6 Schmitz, H.E., Atassi, H., and Atassi, M.Z., "Production Of  
7 Monoclonal Antibodies To Surface Regions That Are  
8 Non-Immunogenic In A Protein Using Free Synthetic Peptide As  
9 Immunogens: Demonstration With Sperm-whale Myoglobin",  
10 Immunological Communications, 12, 161-175, (1983)), even in  
11 these cases the antibody response was enhanced by linking of  
12 the peptides to a protein carrier (Sanchez, Y.,  
13 Ionescu-Matiu, I., Sparrow, J.T., Melnick, J.L., Dreesman,  
14 G.R., "Immunogenicity Of Conjugates And Micelles Of  
15 Synthetic Hepatitis B Surface Antigen Peptides",  
16 Intervirology, 18, 209-213, (1982)).

17           For commonly used protein carriers there is a  
18 strong immune response to the carrier, as well as the  
19 synthetic peptide. Thus, it would be advantageous to evoke  
20 an anti-HBs response with peptides by use of non-protein  
21 carriers, which themselves do not evoke an antibody  
22 response.

23           The possible use of several distinct vaccines in  
24 prophylaxis would be facilitated by the availability of  
25 fully synthetic immunogens.  
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DEFINITIONSAmino Acid Code Words (as appearing in Fig. 2)

1			
2			
3	D	Asp	aspartic acid
4	N	Asn	asparagine
5	T	Thr	threonine
6	S	Ser	serine
7	E	Glu	glutamic acid
8	Q	Gln	glutamine
9	P	Pro	proline
10	G	Gly	glycine
11	A	Ala	alanine
12	C	Cys	cysteine
13	V	Val	valine
14	M	Met	methionine
15	I	Ile	isoleucine
16	L	Leu	leucine
17	Y	Tyr	tyrosine
18	F	Phe	phenylalanine
19	W	Trp	tryptophane
20	K	Lys	lysine
21	H	His	histidine
22	R	Arg	arginine
23			
24	<u>HBV</u>		hepatitis B virus
25	<u>HBsAg</u>		hepatitis B surface antigen.
26	<u>DNA</u>		deoxyribonucleic acid
27			
28			
29			
30			

SUMMARY OF THE INVENTION

1  
2 The applicants have found that antibodies to the  
3 pre-S protein appear early in the course of hepatitis B  
4 infection and probably play the role of antibodies  
5 eliminating HBV from the circulation and thus interrupting  
6 further spread of the infection. Antibodies to the pre-S  
7 protein are likely to represent virus-neutralizing  
8 antibodies. The failure of some hepatitis B vaccines to  
9 elicit such antibodies may be of considerable biological  
10 significance, as indicated by poor immunoprophylactic  
11 effects elicited by such vaccines in some populations,  
12 despite a detectable immune response to the S-protein.

13 Applicants have discovered that amino acid  
14 sequences coded for by the pre-S region of the env gene of  
15 hepatitis B virus (HBV) DNA carry dominant antigenic  
16 determinants common to intact and denatured HBsAg.  
17 Applicants have found that immuno-dominant disulfide bond-  
18 independent epitopes recognized by human antibodies to  
19 hepatitis B virus (HBV) exist within proteins containing  
20 amino acid sequences coded by the pre-S region of HBV DNA,  
21 and more particularly within proteins containing an  
22 N-terminal portion (coded for the pre-S region of HBV DNA)  
23 having an N-terminal methionine at amino acid sequence  
24 position pre-S 120. Applicants further discovered that  
25 peptides corresponding to amino acid sequences in the pre-S  
26 region, and more particularly in the aforementioned region  
27  
28  
29  
30

1 starting at amino acid 120 of the env gene open reading  
2 frame, inhibit the reaction between human anti-HBs and P33  
3 (P36), are highly immunogenic, and elicit high levels of  
4 group-specific antibodies against HBsAg and HBV. The  
5 immunogenicity of such peptides is enhanced by covalent  
6 linking to novel lipid vesicle (liposome) carriers also  
7 discovered by applicants.

8           Glutaraldehyde-fixed liposomes were found by  
9 applicants to be preferred carriers for the peptides of the  
10 invention for inducing anti-HBs.

11           The present invention thus concerns a hepatitis B  
12 peptide immunogen including a peptide containing an amino  
13 acid chain corresponding to at least six consecutive amino  
14 acids within the pre-S gene coded region of the envelope of  
15 HBV. The hepatitis B peptide immunogen being free of an  
16 amino acid chain corresponding to the naturally occurring  
17 envelope proteins of hepatitis B virus.

18           The naturally occurring envelope proteins of  
19 hepatitis B virus include the following:  
20

21           (1) a full length translational product of the  
22 env gene of HBV, i.e., for adw<sub>2</sub> and adr pre-S(1-174) +  
23 S(175-400)=400 amino acids, for ayw, adyw and adw  
24 pre-S(12-174) + S(1-226) = 389 amino acids (env 12-400);

25           (2) pre-S(120-174) + S(175-400) = 281 amino acids  
26 (env 120-400) = terminal 55 amino acids in the pre-S region  
27  
28  
29  
30

1 + 226 amino acids comprising the entire S region (the  
2 corresponding proteins approximately 33 and 36 kD in size  
3 (P33 and P36), and differing from each other in the extent  
4 of glycosylation); and

5 (3) S(1-226) = 226 amino acids, i.e., the entire  
6 S region (env 175-400); representing the approximately 22  
7 and 26 kD major constituents of the HBV envelope (P22 and  
8 P26) in their non-glycosylated and glycosylated forms (the  
9 "S-protein").

10 In an embodiment of the hepatitis B peptide  
11 immunogen of the present invention, the corresponding chain  
12 of amino acids lies between the sequence positions pre-S 120  
13 and pre-S 174. In another embodiment of the invention, the  
14 chain of amino acids is between sequence positions pre-S 1  
15 and pre-S 120. In a further embodiment of the invention,  
16 the corresponding chain of amino acids includes the  
17 methionine amino acid at sequence position pre-S 120. In  
18 still another embodiment, the chain of amino acids is an  
19 amino acid chain containing at least 26 amino acids in the  
20 pre-S region. Still further, the chain of amino acids  
21 containing at least 26 amino acids can correspond to a chain  
22 of at least 26 consecutive amino acids disposed between  
23 sequence position pre-S 120 and sequence position pre-S 174.  
24 Generally the peptide has no more than 280 amino acids,  
25 preferably no more than 225 amino acids, more preferably no  
26

1 more than 174 amino acids, even more preferably no more than  
2 100 amino acids, and still more preferably, no more than 50  
3 amino acids. The vaccine of the present invention can be  
4 composed solely of a peptide, or preferably of a peptide  
5 joined to a carrier. Such carrier can be a conventional  
6 carrier, or a novel carrier according to the present  
7 invention as described hereinbelow.

8 The hepatitis B peptide immunogen of the present  
9 invention is free of any serum proteins, e.g., blood serum  
10 proteins.

11 The present invention also concerns a hepatitis B  
12 vaccine including a peptide containing an amino acid chain  
13 corresponding to at least six consecutive amino acids within  
14 the pre-S gene coded region of the envelope of HBV, and a  
15 physiologically acceptable diluent, e.g., phosphate buffered  
16 saline. The hepatitis B peptide vaccine being free of an  
17 amino acid chain corresponding to the naturally occurring  
18 envelope proteins of hepatitis B virus.

19 The present invention is also directed to a novel  
20 carrier for peptides. In a particularly preferred embodiment  
21 of the present invention, the hepatitis B vaccine containing  
22 an amino acid chain corresponding to a chain of amino acids  
23 in the pre-S region is linked to a carrier via active sites  
24 on the carrier. Still more preferred, the carrier is a lipid  
25 vesicle carrier. Even more preferred, the lipid vesicle  
26 carrier is stabilized by cross-linking.  
27  
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1           The carrier of the present invention includes a  
2 lipid vesicle stabilized by cross-linking and having  
3 covalently bonded active sites on the outer surface thereof.  
4 The synthetic peptide is bonded via such active sites on the  
5 carrier to the outer surface of the lipid vesicle. Such  
6 active sites include  $\text{-COOH}$ ,  $\text{-CHO}$ ,  $\text{-NH}_2$  and  $\text{-SH}$ . Such  
7 stabilization by cross-linking is accomplished by a  
8 stabilizing agent such as an aldehyde having at least two  
9 functional groups, such as a bifunctional aldehyde, for  
10 example, glutaraldehyde. The carrier of the present  
11 invention is chemically cross-linked with pendant functional  
12 groups.

13  
14           The present application also concerns diagnostic  
15 methods. The present invention relates to processes for  
16 detecting the presence of either pre-S gene coded  
17 hepatitis B antigens or antibodies in a serum.

18           Antibodies to the synthetic peptides disclosed  
19 herein can be detected in samples by a process which  
20 comprises:

21           a) contacting the sample with a solid substrate  
22 coated with a non-labelled peptide containing an amino acid  
23 chain corresponding to at least six consecutive amino acids  
24 within the pre-S gene coded region of the envelope of HBV,  
25 the peptide free of an amino acid sequence corresponding to  
26 the naturally occurring envelope proteins of hepatitis B  
27 virus, incubating and washing said contacted sample;

28           b) contacting the incubated washed product  
29 obtained from step a above with a labelled peptide  
30

1 containing an amino acid chain corresponding to at least six  
2 consecutive amino acids within the pre-S gene coded region  
3 of the envelope of HBV, said peptide free of an amino acid  
4 sequence corresponding to the naturally occurring envelope  
5 protein of hepatitis B virus, incubating and washing the  
6 resultant mass; and

7 c) determining the extent of labelled peptide  
8 present in the resultant mass obtained by step b above.

9 Such a process is normally performed using a solid  
10 substrate which is substantially free of available protein  
11 binding sites. Such as by binding sites unbound by  
12 unlabelled peptide with a protein binding site occupier,  
13 e.g., albumin.

14 Another process for detecting such antibodies  
15 comprises:

16 a) contacting the sample with a solid substrate  
17 coated with a non-labelled peptide containing an amino acid  
18 chain corresponding to at least six consecutive amino acids  
19 within the pre-S gene coded region of the envelope of HBV,  
20 the peptide free of an amino acid sequence corresponding to  
21 the naturally occurring envelope proteins of hepatitis B  
22 virus, incubating and washing said contacted sample;

23 — b) contacting the incubated washed product  
24 obtained from step a above with labelled antibody to human  
25 or animal immunoglobulin product by contact with an  
26 immunogen comprising a peptide corresponding to at least six  
27 consecutive amino acids within the pre-S gene coded region  
28 of the envelope of HBV, the peptide immunogen free of an  
29 amino acid sequence corresponding to the naturally occurring  
30



1 envelope proteins of hepatitis B virus, incubating and  
2 washing the contacted sample, and

3 c) determining the extent of labelled antibody  
4 present in the resultant mass of step b.

5 HBV or HBsAg can be detected in a sample by a  
6 process which comprises:

7 a) contacting a first portion of a composition  
8 containing an antibody produced by introducing into an  
9 animal or human an immunogen comprising a peptide  
10 corresponding to at least six consecutive amino acids within  
11 the pre-S gene coded region of the envelope of HBV, the  
12 peptide immunogen free of an amino acid sequence  
13 corresponding to the naturally occurring envelope proteins  
14 of hepatitis B virus, with a mixture of said sample and the  
15 immunogen which has been labelled, incubating and washing  
16 the first portion;

17 b) contacting a second portion of the  
18 composition containing antibody with the same amount of the  
19 labelled immunogen in an antigen free control, incubating  
20 and washing the second portion;

21 c) adding the same amount of Staphylococci  
22 bearing protein A to each of the compositions of steps a and  
23 b above, incubating both of the compositions, centrifuging  
24 each of the compositions and separating liquid from the  
25 solids therein;

26 d) determining the extent of labelled immunogen  
27 in each of the resultant compositions from step c above, and

28 e) comparing the relative amount of labelled  
29 immunogen in each such that if the activity of the resultant  
30

1 composition containing the first portion is less than the  
2 activity for the resultant composition of the second  
3 portion, then the sample contains HBV or HBsAg.

4 The synthetic immunogens can be used in general in  
5 both sandwich type immunoassays and competition type  
6 immunoassays, such as those immunoassays in which antigen in  
7 the sample competes with labelled immunogen for antibody.

8 These and other suitable immunoassay schemes for  
9 use in connection with the synthetic immunogens of this  
10 invention and antibodies thereto are disclosed in copending  
11 application Serial No. 426,309, filed September 29, 1982,  
12 entitled Labelled Peptides As Diagnostic Reagents, assigned  
13 to one of the assignees hereof, the disclosure of which is  
14 hereby incorporated herein by reference.

15 The present invention also concerns a diagnostic  
16 test kit for detecting hepatitis B virus in sera comprising  
17

18 a) antibodies to a peptide containing an amino  
19 acid chain corresponding to at least six consecutive amino  
20 acids within the pre-S gene coded region of the envelope of  
21 HBV, the peptide being free of an amino acid chain  
22 corresponding to the naturally occurring envelope proteins  
23 of hepatitis B virus, attached to a solid support,

24 — c) labelled antibodies to the peptide or to  
25 hepatitis B virus.

26 The kit can comprise a set of instructions for  
27 effecting an immunoassay wherein the effect of formation of  
28 an immune complex is revealed by said labelled antibody.

29 The present invention also concerns a diagnostic  
30 kit for detecting the presence of antibodies to pre-S gene

1 coded antigens of hepatitis B virus in a test sample  
2 comprising

3 a) a given amount of a peptide containing  
4 an amino acid chain corresponding to at least six  
5 consecutive amino acids within the pre-S gene coded region  
6 of the envelope of HBV, the peptide being free of an amino  
7 acid chain corresponding to the naturally occurring envelope  
8 proteins of hepatitis B virus. The peptide is attached to a  
9 solid support, e.g., a water insoluble solid support.

10 b) labelled antibodies, e.g., radiolabeled  
11 or enzyme labelled, to human IgG and/or IgM.

12 The kit can comprise a set of instructions for  
13 effecting an immunoassay, wherein the extent of formation of  
14 an immune complex is revealed by said labelled antibodies.

15 In a particular aspect, the present invention  
16 concerns a process for the detection of antigens coded for  
17 the pre-S gene in sera of HBV infected humans and certain  
18 animals, for example, chimpanzees, comprising the following  
19 steps:

20 (a) coating a solid substrate with  
21 antibodies to a peptide having an amino acid chain  
22 corresponding to at least six consecutive amino acids within  
23 the pre-S gene of HBV DNA, the peptide being free of an  
24 amino acid sequence corresponding to the naturally occurring  
25 envelope proteins of HBV,

26 (b) washing the coated substrate;

27 (c) contacting the washed coated substrate,  
28 e.g., polystyrene beads; with a protein-containing solution;

29 (d) washing the substrate from step c;  
30

- 1 (e) incubating the substrate from step d  
2 with a sample suspected to contain HBV or HBsAg;  
3 (f) washing the substrate from step e;  
4 (g) adding radiolabeled or enzyme-labeled  
5 antibody, the antibody being an antibody to the peptide or  
6 HBsAg;  
7 (h) incubating the substrate from step g;  
8 (i) washing the substrate from step h; and  
9 (j) subjecting the substrate of step i to  
10 counting in a gamma counter, or measuring its enzymatic  
11 activity.

12 The above process can be conducted using ELISA  
13 techniques rather than RIA detection techniques.

14 In a particular embodiment, the present invention  
15 also relates to a process for the detection of antibodies to  
16 proteins coded for by the pre-S region of hepatitis B virus  
17 DNA, comprising the following steps:  
18

19 (a) adsorbing on a solid substrate  
20 containing binding sites thereon, e.g., polystyrene beads, a  
21 peptide having an amino acid sequence corresponding to at  
22 least six consecutive amino acids within the pre-S gene  
23 coded region of the HBV envelope, the peptide being free of  
24 an amino acid sequence corresponding to the naturally  
25 occurring envelope proteins of hepatitis B virus,

26 (b) contacting the substrate from step a  
27 with a material to saturate the binding sites thereon,

28 (c) washing the substrate from step b,

29 (d) contacting the substrate from step c  
30 with a specimen comprising human sera,

- 1 (e) incubating the resultant mass of step d,
- 2 (f) washing the resultant mass of step e,
- 3 (g) adding radiolabeled antibodies to human
- 4 IgG or IgM to the resultant mass of step f to form a second
- 5 resultant mass,
- 6 (h) subjecting the second resultant mass of
- 7 step g to counting in a gamma counter,
- 8 (i) subjecting normal sera utilized as a
- 9 control to steps (a) to (h) and
- 10 (j) comparing the counts of steps h and i.

11 In the above process for the detection of  
12 antibodies, ELISA techniques can be substituted for RIA  
13 techniques.

14 The present invention also relates to a process  
15 for predicting the outcome of hepatitis B infection which  
16 comprises carrying out an immunoassay on serum of a human to  
17 detect the presence of an antibody to an antigen coded for  
18 by the pre-S gene coded region of the envelope of hepatitis  
19 B virus employing the above-described hepatitis B peptide  
20 immunogen at regular intervals and evaluating the data.

21 The present invention further relates to a process  
22 for determining if a human who has been vaccinated with a  
23 vaccine against hepatitis B has become immune to hepatitis B  
24 virus. Such process involves effecting a plurality of  
25 immunoassays of serum from such human to determine if there  
26 are antibodies in the serum to an antigen coded by the pre-S  
27 gene coded region of the envelope of hepatitis B virus  
28 employing the above-described hepatitis B peptide immunogen,  
29 the immunoassays being performed on serum taken from the  
30

1 human at different times.

2 The present invention further concerns a method  
3 for detecting the presence of hepatitis B virus infection  
4 comprising effecting quantitative immunoassays on a serum  
5 sample taken from a human to determine the amount of  
6 antibodies present therein which are antibodies to an  
7 antigen coded by the pre-S gene coded region of the envelope  
8 of the hepatitis B virus employing the above-described  
9 hepatitis B peptide immunogen and comparing the value with a  
10 known standard.

11 The present invention further concerns a method  
12 for detecting the presence of hepatitis B virus infection  
13 comprising effecting quantitative immunoassays on a serum  
14 sample taken from a human to determine the amount of  
15 antigens coded by the pre-S gene coded region of the  
16 envelope of the hepatitis B virus employing the above-  
17 described antibodies to the hepatitis B peptide immunogen  
18 and comparing the value with a known standard.

19 The present invention also related to a process  
20 for raising antibodies which involves introducing into an  
21 animal the above-described hepatitis B peptide immunogen.

22 Still further, the present invention concerns a  
23 process for synthesizing His and Trp containing peptides  
24 which includes the steps of

- 25
- 26 a. linking a first amino acid containing an  
27 alpha-amino protecting group to a resin;
  - 28 b. removal of the alpha-amino protecting group;
  - 29 c. coupling a second amino acid containing an  
30 alpha-amino protecting group to the first amino acid;

1           d. repeating steps b and c by coupling further  
2           alpha-protected amino acids to produce a desired peptide,  
3           wherein at least one of the amino acids is His and wherein  
4           at least one of said amino acids is Trp,

5           e. cleaving the peptide from the resin and  
6           removing remaining protective groups to said first amino  
7           acids;

8           f. substituting a His(ImDNP) for the His;

9           g. substituting a Trp(InFormyl) for the Trp;

10          h. removing the DNP prior to the cleavage and  
11          the removing of protective groups, and

12          i. removing the Formyl during the cleavage and  
13          the removing of protective groups.

14          The present invention further concerns a  
15          prophylactic method of protecting a patient against becoming  
16          infected with hepatitis B comprising administering to such  
17          patient, e.g., a human, an effective dosage of a vaccine as  
18          described hereinabove

19                   BRIEF DESCRIPTION OF THE DRAWINGS

20                  Fig. 1 shows the results of submitting reduced  
21                  HBsAg disassociated into its constituent polypeptides to  
22                  SDS-polyacrylamide gel electrophoresis ("SDS-PAGE") in urea.  
23                  Panel a shows the separated proteins detected by a silver  
24                  stain and panel b is a Western blot with human antiserum to  
25                  hepatitis B.  
26

27                  Fig. 2 shows amino acid sequences of the  
28                  translational products of the pre-S gene region deduced from  
29                  sequences of HBV DNA. The sequences are presented in  
30                  one-letter amino acid code words (such code words are

1 defined in the Definitions herein). Sequences for five  
2 distinct HBV subtypes are presented. The 6th bottom line  
3 shows amino acid residues common to all five subtypes.

4 Fig. 3 shows a profile of relative hydrophilicity  
5 corresponding to the amino acid sequence of the pre-S gene  
6 product. Profiles for subtypes other than ayw are similar.  
7 The portion of the profile to the right from methionine 175  
8 represents the S-gene translation product.

9 Fig. 4 shows two sets of bar graphs for mean  
10 antibody responses of rabbits immunized with free pre-S  
11 120-145 (Fig. 4A) and with the same peptide linked to  
12 cross-linked liposomes containing L-tyrosine-azobenzene  
13 -p-arsenate (RAT) groups (Fig. 4B). Anti-HBs (antibodies to  
14 HBsAg), cross-hatched columns; anti-pre-S 120-145,  
15 diagonally hatched columns. Similar results to Fig. 4B were  
16 obtained with liposomes lacking RAT groups, except that  
17 responses after six weeks were lower. Columns corresponding  
18 to time = 0 represent sera before immunization.

19 Fig. 5 depicts radioimmunoassays with serial  
20 dilutions of a serum from a rabbit immunized with pre-S  
21 120-145 linked to liposomes. Anti-HBs (antibodies to HBsAg),  
22  $\otimes$ ; anti-pre-S 120-145,  $\circ$ . Counts per minute (cpm)  
23 corresponding to distinct dilutions of the pre-immune serum  
24 were subtracted from cpm corresponding to dilutions of  
25 anti-pre-S 120-145; the difference was plotted. The endpoint  
26 titer of the serum (1/163,840) corresponds to its highest  
27 dilution at which the cpm were  $\geq 2.1$  higher than those  
28 corresponding to the same dilution of the pre-immune serum.  
29  
30



1           Fig. 6 shows the reaction of anti-pre-S 120-145  
2 with P33 and P36 in a Western blot (similar to Fig. 1).

3           Fig. 7 shows a graph depicting a diagnostic test  
4 for hepatitis B antigens based on polystyrene beads coated  
5 with anti-pre-S 120-145.

6           Fig. 8 depicts a plot representing the compilation  
7 of antibody responses of individual rabbits to conjugates of  
8 S135-155 (amino acids 309 to 329 of the open reading frame  
9 of the HBV env gene). The type of conjugates is indicated by  
10 numbers defined in Table 1. Antibodies in sera obtained two  
11 weeks after the third immunization were assayed using a  
12 S135-155- beta-galactosidase conjugate and Pansorbin  
13 (Neurath et al., 1982, supra). Their relative titer is given  
14 in comparison with antibody levels induced by a S135-155-KLH  
15 conjugate. Results of anti-HBs assays by RIA (AUSRIA test,  
16 Abbott Laboratories, North Chicago, Illinois) are given in  
17 international milliunits (mIU/ml; Neurath et al., 1982  
18 supra). The line corresponds to the calculated linear  
19 regression that best fits the set of all data concerning  
20 rabbits with an anti-HBs response. The calculated  
21 correlation coefficient (= 0.55) indicates a poor  
22 correlation between anti-HBs and anti-S135-155 responses.

23           Fig. 9 shows four sets of bar graphs (Fig. 9A,  
24 Fig. 9B. Fig. 9C and Fig. 9D) depicting examples of time  
25 courses of antibody responses in rabbits immunized with  
26 distinct S135-155-conjugates (indicated by numbers in each  
27 panel and defined in Table 1). Fig. 9A corresponds to  
28 conjugate No. 5; Fig. 9B corresponds to conjugate No. 11;  
29 Fig. 9C corresponds to conjugate No. 12 and Fig. 9D  
30

1 corresponds to conjugate No. 19. Anti-HBs (dashed columns)  
2 and anti-S-135-155 (black columns) were assayed as described  
3 for Fig. 8.

4 Fig. 10 shows four plots (A, B, C and D) which  
5 depict the kinetics of antibody responses to peptide  
6 pre-S(120-145) (■) and to pre-S protein within  
7 approximately 22nm spherical HBsAg particles (▣) elicited  
8 by unconjugated peptide pre-S(120-145) (plot A) and by the  
9 same peptide linked to cross-linked, cysteine-activated  
10 liposomes with attached RAT (L-tyrosine  
11 azobenzene-p-arsenate) groups (plot B); and the effect of  
12 carrier on anti-peptide antibody titers in sera of rabbits  
13 immunized with 4 doses of peptides pre-S(120-145) (plot C)  
14 and pre-S(12-32) (plot D) given 2 weeks apart. The carriers  
15 for plots C and D were: (1) none; (2) keyhole limpet  
16 hemocyanin (KLH); (3) alum; (4) and (5) cross-linked,  
17 cysteine-activated liposomes with or without attached RAT  
18 groups. Complete and incomplete Freund's adjuvant was used  
19 in all cases except (3).

21 Fig. 11 shows two plots for radioimmunoassays of  
22 IgG antibodies in serial dilutions of rabbit antisera: to  
23 pre-S(120-145) (⊗); to HBV particles and tubular forms of  
24 HBsAg (○), devoid of antibodies to S-protein detectable by  
25 RIA and to a fusion protein of chloramphenicol  
26 acetyltransferase with the sequences of pre-S protein  
27 lacking the 41 C-terminal amino acid residues (□); and of  
28 IgG (Δ) and IgM (▲) antibodies in serum of a patient  
29 recovered from hepatitis B. The latter serum was drawn  
30 before antibodies to the S-protein were detectable. Immulon

2 Removable strings (Dynatech Laboratories) were coated with  
 20  $\mu$ g/ml of either free peptide pre-S(120-145) or  
 pre-S(12-32) and post-coated with gelatin (2.5 mg/ml in 0.1  
 M Tris, pH 8.8). The conditions for coating and the double  
 antibody RIA are described in A.R. Neurath, S.B.H. Kent, N.  
 Strick, Science, 224, 392 (1984) and A.R. Neurath, S.B.H.  
 Kent, N. Strick, Proc. Natl. Acad. Sci USA, 79, 7871 (1982).

Fig. 12 shows a plot depicting the inhibition of  
 the reaction of anti-pre-S(120-145) IgG (antiserum diluted  
 1:100) with a pre-S(120-145)- $\beta$ -galactosidase conjugate by;  
 free peptide pre-S(120-145) [●]; by 20 nm spherical HBsAg  
 particles [▲] and by HBV particles [■]. The latter two  
 preparations contained the same concentration of HBsAg  
 S-protein as determined by radioimmunoassay (AUSRIA, Abbot  
 Laboratories).

Fig. 13 depicts a plot of titers of anti-pre-S  
 (120-145) antibodies versus days of surveillance and  
 indicates the development of IgM [●] and IgG [■]  
 antibodies to the pre-S gene coded protein of HBV during  
 acute hepatitis B.

Fig. 14 shows a plot for radioimmunoassays of  
 various preparations containing HBV-specific proteins on  
 polystyrene beads coated either with anti-pre-S(120-145) I  
 (○, ●, □) or with IgG from a rabbit antiserum against HBV  
 particles and tubular forms of HBsAg (▲, Δ). The tested  
 antigens were: HBV particles and tubular forms (●, Δ);  
 approximately 20 nm spherical particles of HBsAg isolated  
 from plasma (○, Δ); and the latter particles treated with

1 pepsin (1 mg/ml HBsAg, 50 µg/ml pepsin in 0.1 M glycine-HCl, ...  
2 pH 2.2, 2 hours at 37°C) (□).

3 Fig. 15 depicts a plot for radioimmunoassays of  
4 polymerized albumin-binding sites associated with HBsAg  
5 isolated from human plasma and containing pre-S gene coded  
6 sequences (o) or with HBsAg produced in yeast transfected  
7 with recombinant DNA containing the HBV DNA S-gene and thus  
8 lacking pre-S gene coded sequences (o).  
9

#### 10 DETAILED DESCRIPTION OF THE INVENTION

11 Amino acid sequences deduced from sequences of the  
12 pre-S portion of the env genes corresponding to several HBV  
13 subtypes (see Fig. 2) have the following properties distinct  
14 from those of the S-protein: (i) high hydrophilicity and  
15 high percentage of charged residues (E. Schaeffer, J.J.  
16 Sninsky, Pro. Natl. Acad. Sci. USA, 81, 2902 (1984)); (ii)  
17 absence of cysteine residues; (iii) the highest  
18 subtype-dependent variability among HBV DNA gene products;  
19 and (iv) little homology with analogous sequences  
20 corresponding to nonhuman hepadnaviruses (F. Galibert, T.N.  
21 Chan, E. Mandart, J. Virol., 41, 51, (1982)). These  
22 properties suggest that the pre-S gene coded portion of the  
23 HBV envelope is exposed on the surface of the virion, is a  
24 target for the host's immune response and is responsible for  
25 the host range of HBV (limited to humans and some primates).  
26 Synthetic peptides and antibodies against them, having  
27 predetermined specificity offer the opportunity to explore  
28 the biological role of the pre-S protein moiety of the HBV  
29 envelope.  
30

1 Cleavage of disulfide bonds within HBsAg results  
2 in:

3 (a) a substantial decrease of binding of  
4 polyclonal antibodies (G.N. Vyas, K.R. Rao, A.B. Ibrahim,  
5 Science, 178, 1300, (1972); N. Sukeno, R. Shirachi, J.  
6 Yamaguchi, N. Ishida, J. Virol., 9, 182, (1972); G.R.  
7 Dreesman, F.B. Hollinger, R.M. McCombs, J.L. Melnick, J.  
8 Gen. Virol. 19, 129 (1973); and A.R. Neurath, N. Strick, J.  
9 Med. Virol., 6, 309, (1980)) and of some monoclonal  
10 antibodies (J. Pillot, M.M. Riottot, C. Geneste, L.  
11 Phalente, R. Mangalo, Develop. Biol. Stand., in press  
12 (1984)) elicited by intact HBsAg, and

13 (b) reduction of immunogenicity (Y. Sanchez, I.  
14 Ionescu-Matiu, J.L. Melnick, G.R. Dreesman, J. Med. Virol.  
15 11, 115, (1983)). However, some epitopes are resistant to  
16 reduction of disulfide bonds (M. Imai, A. Gotoh, K.  
17 Nishioka, S. Kurashina, Y. Miyakawa, M. Mayumi, J. Immunol.,  
18 112, 416, (1974)). These epitopes are common to all  
19 antigenic subtypes of HBV, but their localization on  
20 envelope components of HBV has not been determined. The  
21 present invention takes advantage of the localization of  
22 disulfide-bond independent antigenic determinants on the  
23 N-terminal portion (coded for by the pre-S gene of HBV DNA)  
24 of the minor HBsAg proteins P33 and P36, and on other  
25 regions of proteins coded for by the pre-S gene.

26 These determinants represent the dominant epitopes  
27 on reduced and dissociated HBsAg reacting with human  
28 anti-HBs. They are mimicked with high fidelity by pre-S  
29 120-145 which elicits antibodies to HBsAg about 400 times  
30

1 more efficiently than a synthetic peptide analogue  
2 corresponding to the S-gene (A.R. Neurath, S.B.H. Kent, and  
3 N. Strick, Proc. Natl. Acad. Sci. USA, 79, 7871 (1982)). No  
4 precedent exists for such high levels of virus-recognizing  
5 antibodies to a synthetic peptide analogue of an HBV  
6 protein. These antibodies could be used in a diagnostic test  
7 permitting the direct detection of the pre-S gene coded  
8 antigenic determinants in serum of HBV carriers.

9           The pre-S gene is the most divergent among all  
10 regions of hepadnavirus genomes (F. Galibert, T.N. Chen, E.  
11 Mandart, J. Virol., 41, 51 (1982)) (HBV is a member of the  
12 hepadnavirus family).

13           The hepatitis B vaccine of the present invention  
14 contains a peptide, either a synthetic peptide (peptide  
15 produced by assembling individual amino acids by chemical  
16 means or by expression vectors (DNA route)) or a peptide  
17 derived from natural sources, such peptide having an amino  
18 acid chain corresponding to at least six consecutive amino  
19 acids within the pre-S gene coded region of the surface  
20 antigen of hepatitis B virus. Such chain can be, for  
21 example, at least 10, 15, 20, or 26 amino acids long. A  
22 preferred peptide according to one embodiment of the present  
23 invention is an amino acid chain disposed between sequence  
24 position pre-S 120 and pre-S 174, and more preferably such  
25 chain includes the N-terminal methionine at sequence  
26 position pre-S 120. A preferred peptide is an amino acid  
27 chain corresponding to the chain between sequence position  
28 pre-S 120 and pre-S 145, i.e., pre-S (120-145).  
29

30

1 Preferred positions of the chain include the  
2 following: (1) The amino acid chain entirely between and  
3 including sequence position pre-S 1 and pre-S 11 for  
4 subtypes  $adw_2$  and  $adr$ , (2) between and including sequence  
5 positions pre-S 10 and pre-S 40, (3) between and including  
6 sequence positions pre-S 15 and pre-S 120, (4) between and  
7 including sequence position pre-S 15 and pre-S 55, and (5)  
8 between and including sequence position pre-S 90 and pre-S  
9 120. A particularly preferred chain according to the  
10 present invention has 26 amino acids, includes the  
11 N-terminal methionine at sequence position pre-S 120 and is  
12 disposed between sequence position pre-S 120 and pre-S 174.

13 Preferred peptides according to the present  
14 invention include the following:

- 15 (1) pre-S(12-32), wherein the sequence is (see  
16 Fig. 2) MGTNLSVPNPLGFFPDHQLDP for subtype  $adw_2$ ;  
17 (2) pre-S(120-145), wherein the sequence is (see  
18 Fig. 2) MQWNSTAFHQTLQDPRVRGLYLPAGG for subtype  $adw_2$ ;  
19 (3) pre-S(32-53), wherein the sequence is (see  
20 Fig. 2) PAFGANSNNPDWDFNPVKDDWP for subtype  $adw_2$ ;  
21 (4) pre-S(117-134), wherein the sequence is (see  
22 Fig. 2) PQAMQWNSTAFHQTLQDP for subtype  $adw_2$ ;  
23 (5) pre-S(94-117), wherein the sequence is (see  
24 Fig. 2) PASTNRQSGRQPTPISPPLRDSHP for subtype  $adw_2$ ;  
25 (6) pre-S(153-171), wherein the sequence is (see  
26 Fig. 2) PAPNIASHISSISARTGDP for subtype  $adw_2$ ;  
27 (7) pre-S(1-21), wherein the sequence is (see  
28 Fig. 2) MGGWSSKPRKGMGTNLSVNP for subtype  $adw_2$ ;  
29  
30

- 1 (8) pre-S(57-73), wherein the sequence is (see  
2 Fig. 2) QVGVGAFGPRLTPPHGG for subtype adw<sub>2</sub>;  
3 (9) pre-S(1-11),  
4 a. for adw<sub>2</sub>, wherein the sequence is (see  
5 Fig. 2) MGGWSSKPRKG  
6 b. for adr, wherein the sequence is (see  
7 Fig. 2) MGGWSSKPRQG.

8 Any analogs of the pre-S gene coded sequences of  
9 the present invention involving amino acid deletions, amino  
10 acid replacements, such as replacements by other amino  
11 acids, or by isosteres (modified amino acids that bear close  
12 structural and spatial similarity to protein amino acids),  
13 amino acid additions, or isosteres additions can be  
14 utilized, so long as the sequences elicit antibodies  
15 recognizing the pre-S protein of HBV or hepatitis B surface  
16 antigen.

17 In the formation of a peptide derived from natural  
18 sources, a protein containing the required amino acid  
19 sequence is subjected to selective proteolysis such as by  
20 splitting the protein with chemical reagents or using  
21 enzymes. Synthetic formation of the peptide requires  
22 chemically synthesizing the required chain of amino acids.

23 — In forming a synthetic vaccine according to the  
24 present invention, it is preferred to insure that the amino  
25 acid chain (peptide residue) corresponding to at least six  
26 consecutive amino acids within the pre-S gene coded region  
27 of hepatitis B virus has the steric configuration to be  
28 recognized by antibody to hepatitis B virus. To this end,  
29 the given chain of amino acids may have bonded thereto as  
30



1 part of the amino acid chain, one or more additional amino  
2 acids on either, or both sides thereof. These additional  
3 amino acids can serve as auxiliary amino acids to enhance  
4 the stabilization of the amino acid chain so that it is  
5 readily recognized by antibody to hepatitis B virus. The  
6 additional amino acids can be the same amino acids in the  
7 same sequence as they occur in the natural protein, or other  
8 amino acids may be employed.

9 In one form of the invention, the peptide having a  
10 chain length of minimally six amino acids can be bounded on  
11 either side thereof with additional amino acids, e.g., three  
12 amino acids on either side of the residue, to form a longer  
13 chain of amino acids. The chain of amino acids may contain  
14 more than one amino acid sequence corresponding to at least  
15 six consecutive amino acids within the pre-S region of the  
16 surface antigen of hepatitis B virus.

17 The length of the individual amino acid sequence  
18 would depend on the method of producing the sequence. If  
19 the sequence is made by assembling individual amino acids by  
20 chemical means, then the sequence length would generally not  
21 exceed 50 amino acids, and preferably would not exceed 40  
22 amino acids. If the synthetic peptide is obtained from a  
23 DNA route, the chain length could be longer, for example,  
24 100 or more amino acids. It is, however, normally shorter,  
25 and optimally considerably shorter than the natural pre-S  
26 protein. Thus, in the embodiment wherein the peptide has  
27 units of both the S region and pre-S region, its peptide  
28 portions corresponding to the S region is shorter than the  
29 natural S protein, e.g., no more than 100 amino acids,  
30

1 preferably no more than 40 amino acids and usually less than  
2 30 amino acids. In such cases, the peptide portion  
3 corresponding to the pre-S region can be of a length  
4 corresponding to the entire pre-S region, but generally is  
5 less than the entire pre S region.

6 When the peptide contains no components  
7 corresponding to the amino acid sequence of the S region, it  
8 can contain amino acid sequences corresponding to the entire  
9 pre-S region, or shorter than the entire pre-S region.

10 Where, however, the amino acid sequence is part of  
11 a long chain, such as when there are more than one sequence  
12 of amino acids, the chain can contain residues of various  
13 moieties, for example, segments of polyamino acids or  
14 polysaccharides.

15 In addition to containing one or more different or  
16 the same sequences of amino acids corresponding to at least  
17 six consecutive amino acids within the pre-S region of  
18 hepatitis B virus, e.g., containing more than one sequence  
19 of amino acids corresponding to different epitopes  
20 (antigenic determinants) in the pre-S region of hepatitis B  
21 virus, the vaccine of the present invention can contain  
22 amino acid chains containing epitopes of different antigens  
23 or allergens so as to form a vaccine directed to hepatitis B  
24 virus and to one or more additional diseases, e.g.,  
25 measles, influenza, smallpox, polio, diphtheria, just to name  
26 a few. Such additional amino acid sequences can be of  
27 varying amino acid chain lengths.

28 A hepatitis B vaccine according to the present  
29 invention can include in addition to one or more amino acid  
30

sequences corresponding to at least six consecutive amino acids within the pre-S region of the surface antigen of hepatitis B virus, one or more amino acid sequences corresponding to consecutive amino acids within the S region of the surface antigen of hepatitis B virus, for example,

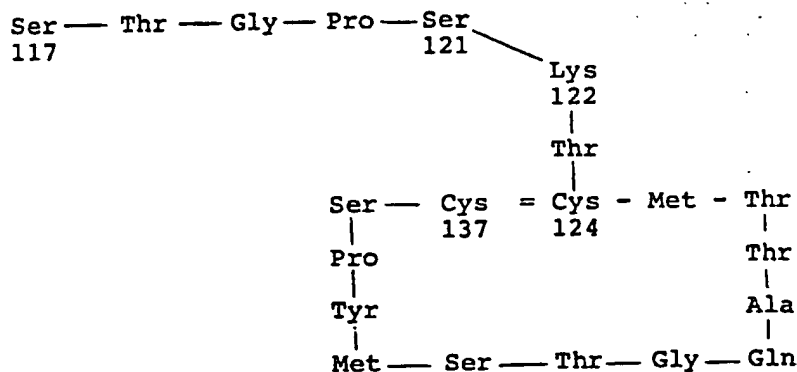
141 142 143 144 145 146  
Lys Pro Thr Asp Gly Asn,

or

138 139 140 141 142 143 144 145 146 147 148 149  
Cys Cys Thr Lys Pro Thr Asp Gly Asn Cys Thr Cys

Other peptides corresponding to antigenic determinants of HBsAg (S region) and thus combinable in the same chain with one or more amino acids sequences corresponding to at least six amino acids in the pre-S region of HBsAg include the following:

(1)



(2) Position

Amino Acid Series

48-81 Cys-Leu-Gly-Gln-Asn-Ser-Gln-Ser-Pro-Thr-  
Ser-Asn-His-Ser-Pro-Thr-Ser-Cys-Pro-Pro-  
Thr-Cys-Pro-Gly-Thr-Arg-Trp-Met-Cys-Leu-  
Arg-Arg-Phe-Ile

- 1 (3, 2-16 Glu-Asn-Ile-Thr-Ser-Gly-Phe-Leu-Gly-Pro-  
2 Leu-Leu-Val-Leu-Gln-Cys  
3  
4 (4) 22-35 Leu-Thr-Arg-Ile-Leu-Thr-Ile-Pro-Gln-Ser-  
5 Leu-Asp-Ser-Trp-Cys  
6  
7 (5) 38-52 Ser-Leu-Asn-Phe-Leu-Gly-Gly-Thr-Thr-Val-  
8 Cys-Leu-Gly-Gln-Asn  
9  
10 (6) 47-52 Val-Cys-Leu-Gly-Gln-Asn  
11  
12 (7) 95-109 Leu-Val-Leu-Leu-Asp-Tyr-Gln-Gly-Met-Leu-  
13 Pro-Val-Cys-Pro-Leu  
14 (8) 104-109 Leu-Pro-Val-Cys-Pro-Leu

15 The sequences of amino acids can be interconnected  
16 with one another such as by cross-linking or by being bonded  
17 directly thereto in the form of a branched chain, or the  
18 respective sequences can be bonded to a central "carrier".  
19

20 There is realized by the present invention a  
21 synthetic vaccine which is characterized by the absence of  
22 naturally occurring envelope proteins of hepatitis B virus,  
23 i.e., the vaccine of the present invention is composed of  
24 one or more peptide sequences corresponding to a limited  
25 — portion of the hepatitis B virus envelope protein. The  
26 vaccine of the present invention is also free of other  
27 proteins found in the virion. Vaccines can be synthesized  
28 which are free of biologically produced components, free of  
29 viral components whether they be active or inactive, free of  
30 antibodies, free of deoxyribonucleic acid (DNA), and are

1 therefore likely to be substantially free from undesirable  
2 side effects commonly found with other vaccines (e.g.,  
3 unintentional infection with virus, allergic reactions,  
4 fevers, etc.).

5           It should be understood that the vaccine of the  
6 present invention can be in admixture with other proteins  
7 and these proteins include the proteins of known antigens or  
8 allergens. Thus when it is stated herein that the vaccine  
9 is characterized by the absence of an amino acid sequence  
10 corresponding to the naturally occurring envelope proteins  
11 of the hepatitis B virus it is meant that notwithstanding  
12 the absence of such proteins, the composition functions as a  
13 vaccine, i.e., provides protective immunization by formation  
14 of antibodies.

15           The peptide of the present invention is such that  
16 it is capable of forming "neutralizing antibodies", i.e.,  
17 antibodies that will protect patients against hepatitis B  
18 virus. Accordingly, the present invention is also directed  
19 to methods for protecting a patient against contracting  
20 hepatitis B.

21           The peptides and vaccines of the present invention  
22 can be used to improve immune response and to overcome  
23 non-responsiveness to certain known hepatitis B virus  
24 vaccines (e.g., containing no peptides corresponding to  
25 amino acid sequences in the pre-S region).

26           The peptides of the present invention can be  
27 utilized in conjunction with peptides containing amino acid  
28 chains corresponding to consecutive amino acids within the S  
29 gene coded region of HBsAg. Also, embodied by the present  
30

1 invention is a peptide containing amino acids corresponding  
2 to consecutive amino acids spanning both the pre-S and S  
3 region, e.g., pre-S 160 to S 20.

4 A carrier may be provided for the synthetic  
5 peptide of the invention. It should be understood, however,  
6 that a carrier may not be required to practice the present  
7 invention, i.e., a carrier may not be required to produce  
8 antibodies according to the present invention.

9 The "carrier" is simply a physiologically  
10 acceptable mass to which the synthetic peptide is attached  
11 and which is expected to enhance the immune response. A  
12 carrier can comprise simply a chain of amino acids or other  
13 moieties and to that end it is specifically contemplated to  
14 use as a carrier a dimer, oligomer, or higher molecular  
15 weight polymer of a sequence of amino acids defining a  
16 synthetic peptide of the invention. In other words, having  
17 determined the desired sequence of amino acids to form the  
18 synthetic peptide, these amino acids can be formed from  
19 naturally available materials or synthetically and can be  
20 polymerized to build up a chain of two or more repeating  
21 units so that repeating sequences serve both as "carrier"  
22 and synthetic peptide. Stated differently, an independent  
23 carrier may not be required. Alternatively, additional amino  
24 acids can be added to one or both ends of the amino acid  
25 chain that defines the synthetic peptide. It is preferred  
26 that alternative carriers comprise some substance, animal,  
27 vegetable or mineral, which is physiologically acceptable  
28 and functions to present the synthetic peptide so that it is  
29 recognized by the immune system of a host and stimulates a  
30

1 satisfactory immunological response. Thus, a wide variety of  
2 carriers are contemplated, and these include materials which  
3 are inert, which have biological activity and/or promote an  
4 immunological response. For instance, proteins can be used  
5 as carriers. Examples of protein carriers include tetanus  
6 toxoid, keyhole limpet hemocyanin, etc.

7 Polysaccharides are also contemplated as carriers,  
8 and these include especially those of molecular weight  
9 10,000 to 1,000,000, including, in particular, starches,  
10 dextran, agarose, ficoll or its carboxy methyl derivative  
11 and carboxy methyl cellulose.

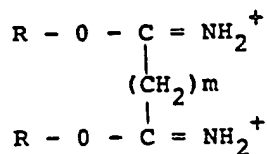
12 Polyamino acids are also contemplated for use as  
13 carriers, and these polyamino acids include, among others,  
14 polylysine, polyalanyl polylysine, polyglutamic acid,  
15 polyaspartic acid and poly (C<sub>2</sub>-C<sub>10</sub>) amino acids.

16 Organic polymers can be used as carriers, and  
17 these polymers include, for example, polymers and copolymers  
18 of amines, amides, olefins, vinyls, esters, acetals,  
19 polyamides, carbonates and ethers and the like. Generally  
20 speaking, the molecular weight of these polymers will vary  
21 dramatically. The polymers can have from two repeating units  
22 up to several thousand, e.g., two thousand repeating units.  
23 Of course, the number of repeating units will be consistent  
24 with the use of the vaccine in a host animal. Generally  
25 speaking, such polymers will have a lower molecular weight,  
26 say between 10,000 and 100,000 (the molecular weight being  
27 determined by ultracentrifugation).

28 Inorganic polymers can also be employed. These  
29 inorganic polymers can be inorganic polymers containing  
30

1 organi. moieties. In particular, silicates and aluminum  
 2 hydroxide can be used as carriers. It is preferred that the  
 3 carrier be one which is an immunological adjuvant. In such  
 4 cases, it is particularly contemplated that the adjuvant be  
 5 muramyl dipeptide or its analogs.

6 The carrier can also be the residue of a  
 7 crosslinking agent employed to interconnect a plurality of  
 8 synthetic peptide containing chains. Crosslinking agents  
 9 which have as their functional group an aldehyde (such as  
 10 glutaraldehyde), carboxyl, amine, amido, imido or  
 11 azidophenyl group. In particular, there is contemplated  
 12 the use of butyraldehyde as a crosslinking agent, a divalent  
 13 imido ester or a carbodiimide. Particularly contemplated  
 14 divalent imido esters are those of the formula



15  
 16  
 17  
 18 wherein m is 1 to 13 and R is an alkyl group of 1 to 4  
 19 carbon atoms. Particularly contemplated carbodiimides for  
 20 use as crosslinking agents include cyclohexylcarboximide,  
 21 ethyldimethylaminopropyl carbodiimide, N-ethylmorpholino  
 22 cyclohexyl carbodiimide and diisopropyl carbodiimide.

23  
 24 Chemical synthesis of peptides is described in the  
 25 following publications: S.B.H. Kent, Biomedical Polymers,  
 26 eds. Goldberg, E.P. and Nakajima, A. (Academic Press, New  
 27 York), 213-242, (1980); A.R. Mitchell, S.B.H. Kent, M.  
 28 Engelhard, and R.B. Merrifield, J. Org. Chem., 43,  
 29 2845-2852, (1978); J.P. Tam, T.-W. Wong, M. Riemen, F.-S.  
 30 Tjoeng, and R.B. Merrifield, Tet. Letters, 4033-4036,



(1979); S. Mojsov, A.R. Mitchell, and R.B. Merrifield, J. Org. Chem., 45, 555-560, (1980); J.P. Tam, R.D. DiMarchi and R.B. Merrifield, Tet. Letters, 2851-2854, (1981); and S.B.H. Kent, M. Riemen, M. Le Doux and R.B. Merrifield, Proceedings of the IV International Symposium on Methods of Protein Sequence Analysis, (Brookhaven Press, Brookhaven, N.Y.), in press, 1981.

Chemical Synthesis: In the so-called "Merrifield solid phase procedure" the appropriate sequence of L-amino acids is built up from the carboxyl terminal amino acid to the amino terminal amino acid. Starting with the appropriate carboxyl terminal amino acid attached to a polystyrene (or other appropriate) resin via chemical linkage to a chloromethyl group, benzhydrylamine group, or other reactive group of the resin, amino acids are added one by one using the following procedure. The peptide-resin is:

- (a) washed with methylene chloride;
- (b) neutralized by mixing for 10 minutes at room temperature with 5% (v/v) diisopropylethylamine (or other hindered base) in methylene chloride;
- (c) washed with methylene chloride;
- (d) an amount of amino acid equal to six times the molar amount of the growing peptide chain is activated by combining it with one-half as many moles of a carbodiimide (e.g., dicyclohexylcarbodiimide, or diisopropylcarbodiimide) for ten minutes at 0°C, to

1 form the symmetric anhydride of the amino  
2 acid. The amino acid used should be  
3 provided originally as the N-alpha-tert.butyl-  
4 oxycarbonyl derivative, with side chains  
5 protected with benzyl esters (e.g. aspartic or  
6 glutamic acids), benzyl ethers (e.g., serine,  
7 threonine, cysteine or tyrosine),  
8 benzyloxycarbonyl groups (e.g., lysine) or other  
9 protecting groups commonly used in peptide  
10 synthesis.

- 11 (e) the activated amino acid is reacted with  
12 the peptide-resin for two hours at  
13 room temperature, resulting in addition  
14 of the new amino acid to the end of the  
15 growing peptide chain.  
16 (f) the peptide-resin is washed with methylene  
17 chloride;  
18 (g) the N-alpha-(tert. butyloxycarbonyl) group is  
19 removed from the most recently added  
20 amino acid by reacting with 30 to 65%, preferably  
21 50% (v/v) trifluoroacetic acid in methylene  
22 chloride for 10 to 30 minutes at room  
23 temperature;  
24 (h) the peptide-resin is washed with methylene  
25 chloride;  
26 (i) steps (a) through (h) are repeated until the  
27 required peptide sequence has been  
28 constructed.  
29

30 The peptide is then removed from the resin and

1 simultaneously the side-chain protecting groups are removed,  
2 by reaction with anhydrous hydrofluoric acid containing 10%  
3 v/v of anisole or other suitable (aromatic) scavenger.  
4 Subsequently, the peptide can be purified by gel filtration,  
5 ion exchange, high pressure liquid chromatography, or other  
6 suitable means.

7 In some cases, chemical synthesis can be carried  
8 out without the solid phase resin, in which case the  
9 synthetic reactions are performed entirely in solution. The  
10 reactions are similar and well known in the art, and the  
11 final product is essentially identical.

12 Isolation from natural sources: If sufficient  
13 quantities of the whole protein antigen are available, a  
14 limited portion of the molecule, bearing the desired  
15 sequence of amino acids may be excised by any of the  
16 following procedures:  
17

- 18 (a) Digestion of the protein by proteolytic  
19 enzymes, especially those enzymes whose  
20 substrate specificity results in cleavage  
21 of the protein at sites immediately  
22 adjacent to the desired sequence of amino  
23 acids;  
24  
25 (b) Cleavage of the protein by chemical means.  
26 Particular bonds between amino acids can be  
27 cleaved by reaction with specific reagents.  
28 Examples include: bonds involving  
29 methionine are cleaved by cyanogen bromide;  
30 asparaginyl-glycine bonds are cleaved by

1 hydroxylamine;

2 (c) A combination of proteolytic and chemical  
3 cleavages.

4 It should also be possible to clone a small  
5 portion of the DNA, either from natural sources or prepared  
6 by synthetic procedures, or by methods involving a  
7 combination thereof, that codes for the desired sequence of  
8 amino acids, resulting in the production of the peptide by  
9 bacteria, or other cells.

10 Analogously, one can form chains containing a  
11 plurality of amino acid sequences by the following  
12 technique: An aqueous solution of a peptide or peptides is  
13 mixed with a water-soluble carbodiimide (e.g., ethyl-  
14 dimethyl-aminopropylcarbodiimide). This results in  
15 polymerization of the peptide(s); depending on the use of  
16 the side chain blocking groups mentioned above, either  
17 straight chain or branched polymers of the peptide can be  
18 made.

19 If desired the synthetic peptide of the present  
20 invention can have bonded thereto a chain of any of the  
21 following moieties: polypeptide, polyamino acid, poly-  
22 saccharide, polyamide or polyacrylamide which can serve as a  
23 stabilizing chain or as a bridge between amino acids of the  
24 individual chains. Such chains are available commercially  
25 or, in the case of polyamino acids, are formed by a process  
26 which comprises: mixing a solution of the desired amino acid  
27 sequence with a solution of the N-carboxylanhydride of the  
28 amino acid and allowing a base-catalyzed polymerization to  
29

30

1 occur, which is initiated by the amine groups of the  
2 peptide.

3 Although a carrier may not be required, if a  
4 carrier is employed the deposition of a chain or chains on a  
5 "carrier" can be effected as follows:

6 1. Protein Carrier: The protein and the  
7 synthetic peptide are dissolved together in water or other  
8 suitable solvent, and covalently linked via amide bonds  
9 formed through the action of a carbodiimide. The resulting  
10 product may contain one or more copies of the peptide per  
11 protein monomer. Alternatively, the reduced peptide may be  
12 added to a carrier containing sulfhydryl groups to form  
13 disulfide bonds. Yet another method involves the addition of  
14 reduced peptide to protein carriers containing maleimidyl  
15 groups to form a covalent linkage by a Michael addition, or  
16 any other covalent attachment means.

17 2. Polysaccharide Carriers: Oligosaccharide  
18 carriers should have molecular weights in the range 1,000 to  
19 1,000,000. In order to covalently link these to synthetic  
20 peptides, suitable functional groups must first be attached  
21 to them. Carboxyl groups may be introduced by reacting with  
22 iodoacetic acid to yield carboxymethylated polysaccharides,  
23 or by reacting with carbonyldiimidazole to yield activated  
24 carbonyl esters. Carboxymethyl polysaccharides are coupled  
25 to the peptide by a carbodiimide reaction, while the  
26 activated carbonyl esters react spontaneously with peptides.  
27 Multiple copies of the synthetic peptide should be attached  
28 to each oligosaccharide unit.  
29  
30

1                   3.   Polyamino Acid Carriers:   These carriers  
2 should have molecular weights in the range 1,000 to  
3 1,000,000. Polylysine and polyornithine have primary amino  
4 groups on their side chains; polyaspartic acid and  
5 polyglutamic acid have carboxyl groups. Peptides may be  
6 coupled to these via amide bonds using the carbodiimide  
7 reaction. Another carrier that provides amino groups for  
8 coupling is polylysine to which polyalanine can be attached  
9 to the side chains of the lysine residues. The synthetic  
10 peptide may be attached to the ends of polyalanine chains,  
11 also by a carbodiimide reaction. Multiple copies of the  
12 synthetic peptide should be attached to each oligopep-  
13 tide unit.

14                   The novel carrier of the present invention  
15 includes a lipid vesicle having active sites on the outer  
16 surface thereof. Such active sites include -COOH, -CHO,  
17 -NH<sub>2</sub> and -SH. The lipid carrier can be stabilized by  
18 cross-linking by a stabilizing agent such as an aldehyde  
19 having at least two functional groups, such as a  
20 bifunctional aldehyde, e.g., glutaraldehyde.

21                   The bonding of the peptide to the lipid vesicle  
22 carrier occurs at the active sites on the lipid vesicle on  
23 the exterior surface of the carrier. Without wishing to be  
24 bound by any theory of operability, it is believed that such  
25 bonding is at least covalent bonding.

26                   It is possible to bind a peptide to two active  
27 sites on the outer surface of the lipid vesicle. For  
28 example, a -NH<sub>2</sub> group at one end of a peptide can bind with  
29 a -COOH active site on the outer surface of the lipid  
30

1 vesicle. The other end of the peptide can then bind with  
2 another active site on the lipid vesicle, for example, a  
3 -COOH group on the other end of the peptide can bind with a  
4 -NH<sub>2</sub> active site on the lipid vesicle.

5 The preferred carrier to support the synthetic  
6 peptides of the present invention is a lipid vesicle. Lipid  
7 vesicles can be formed by sonicating a lipid in an aqueous  
8 medium, by resuspension of dried lipid layers in a buffer or  
9 by dialysis of lipids dissolved in an organic solvent  
10 against a buffer of choice. The latter procedure is  
11 preferred. Lipid vesicles consist of spheres of lipid  
12 bilayers that enclose part of the aqueous medium.

13 Lipid vesicle (non-protein) carriers according to  
14 the present invention can be produced in a variety of ways.  
15 The preferred method to produce such carriers would be to  
16 treat a lipid vesicle containing aminoalkanes and  
17 diaminoalkanes having 10 to 18 carbon atoms, for example  
18 stearylamine, cetylamine and myristylamine with a  
19 polyaldehyde, such as a dialdehyde, for example, butanedial  
20 (succinaldehyde), pentanedial (glutaraldehyde), hexanedial  
21 (adipaldehyde), heptanedial (pimelicaldehyde) and octanedial  
22 (suberaldehyde). Alternatively, a liposome containing  
23 aminoalkenes and diaminoalkenes having 10 to 18 carbon  
24 atoms, for example, oleylamine, can be treated with the  
25 aforementioned polyaldehydes. The lipid vesicle carrier  
26 thus formed has active aldehyde groups on the surface  
27 thereof allowing the direct linking of peptides via their  
28 N-terminal or lysine groups.  
29

30

1                   Peptides linked to lipid vesicle carriers

2 ,according to the present invention can also be prepared by  
3       treating an amino containing lipid vesicle as described  
4       above with a peptide activated by carbodiimide, for example,  
5       N-ethyl-N' (dimethylamino)propyl carbodiimide.

6                   Alternatively a carbodiimide activated peptide is  
7       linked to polyaldehyde, e.g., dialdehyde, treated lipid  
8       vesicles which have been further derivatized by reaction  
9       with a water-soluble diaminoalkane, e.g., ethylene diamine  
10      and propylene diamine.

11                  Still further, lipid vesicles containing fatty  
12      acids (saturated and unsaturated) having 12 to 18 carbon  
13      atoms, e.g., stearic acid, oleic acid, palmitic acid and  
14      myristic acid, are activated with carbodiimide. Thereafter,  
15      the activated lipid vesicle is reacted with a peptide.

16                  Another approach to form a carrier according to  
17      the present invention involves using a fatty acid aldehyde  
18      as a component of the lipid vesicle and treating such lipid  
19      vesicle as described for glutaraldehyde treated lipid  
20      vesicles. Such lipid vesicle reacts directly with amino  
21      groups of peptides.

22                  In a preferred embodiment of a carrier according  
23      to the present invention, the aforementioned lipid vesicle  
24      carrier formed by treating a amino or diaminoalkane (or  
25      amino or diaminoalkene) having 10 to 18 carbon atoms with a  
26      polyaldehyde is further reacted with cysteine (L- or D- or  
27      LD- cysteine). These lipid vesicles are then reacted with a  
28      peptide having -SH groups, i.e., cysteine containing  
29      peptide having -SH groups, i.e., cysteine containing  
30



1 peptides. The link between the lipid vesicle and the  
2 peptide is mediated by a disulfide bond.

3 Alternatively, a fatty acid mercaptan is used as a  
4 component of the lipid vesicle, for example,  
5 octadecanethiol. A cysteine containing peptide is directly  
6 linked to such lipid vesicle.

7 Another approach to form carriers according to the  
8 present invention involves the preparation of the above  
9 described fatty acid mercaptan containing lipid vesicles  
10 which are further reacted with a dimaleimide, for example,  
11 para or ortho N-N'-phenylenedimaleimide. Such lipid vesicle  
12 is then reacted with a cysteine containing peptide.

13 Alternatively, the link between the appropriate  
14 lipid vesicle and the appropriate peptide can be  
15 accomplished by commercially available cross-linking  
16 reagents such as dimethyl adipimidate; dimethyl  
17 3,3'-dithiobis-propionimidate; 2-iminothiolane;  
18 di-succinimidyl suberate; bis[2-(succinimidooxy  
19 carbonyloxy)-ethyl] sulfone; disuccinimidyl tartarate;  
20 dithiobis (succinimidyl propionate); ethylene glycol  
21 bis(succinimidyl succinate); N-5-azido-2-nitrobenzoyloxy-  
22 succinimide; p-azidophenacyl bromide; p-azido-phenylglyoxal  
23 4-fluoro-3-nitrophenyl azide; N-hydroxysuccinimidyl-4-azide.  
24 benzoate; N-hydroxysuccinimidyl-4-azidosalicylic acid; m-  
25 maleimidobenzoyl N-hydroxy succinimide ester; methyl-4-  
26 azidobenzoimidate; p-nitrophenyl 2-diazo-3,3,3-trifluoro-  
27 proprionate; N-succinimidyl-6 (4'-azido-2'-nitrophenylamino  
28 nexanoate; succinimidyl 4-(N-maleimidomethyl) cyclohexane-  
29 1-carboxylate; succinimidyl 4-(p-maleimidomethyl) butyrate;  
30

1 N-(4-azidophenylthio)phthalimide; ethyl 4-aziodophenyl 1,  
2 4-dithiobutyrimidate; N-succinimidyl (4-azidophenyldithio)  
3 propionate; 1-5-difluoro-2, 4-dinitrobenzene;  
4 4,4'-difluoro-3,3'-dinitrodiphenyl-sulfone;  
5 4,4'-diisothiocyano-2,2'-disulfonic acid stilbene;  
6 p-phenylenediisothiocyanate; 4,4'-dithiobisphenylazide;  
7 erythritolbiscarbonate; N-succinimidyl 3-(2-pyridyldithiol)  
8 propionate; dimethyl pimelimidate and dimethyl suberimide.

9 The lipid vesicles according to the present  
10 invention act not only as carriers, but also as adjuvants.

11 The lipid vesicle synthetic carriers of the  
12 present invention can be utilized to bind synthetic peptide  
13 analogues (eliciting protective antibodies) of various  
14 viral, bacterial, allergen and parasitic proteins of man and  
15 animals, besides synthetic peptide analogues of hepatitis B  
16 surface antigen, and especially the novel synthetic peptide  
17 analogue of hepatitis B surface antigen containing amino  
18 acid sequences corresponding to amino acid sequences in  
19 pre-S gene coded region of the HBV.

20 Accordingly, the lipid vesicle synthetic carriers  
21 of the present invention can be used to bind with synthetic  
22 peptide analogues of the following viruses: influenza  
23 hemagglutinin (A/memphis/102/72 strain, A/Eng 1878/69  
24 strain, A/NT/60/68/29c strain, and A/Qu/7/70 strain), fowl  
25 plague virus hemagglutinin, vaccinia, polio, rubella,  
26 cytomegalovirus, small pox, herpes simplex types I and II,  
27 yellow fever, Infectious ectromelia virus, Cowpox virus,  
28 Infectious bovine rhinotracheitis virus, Equine rhino-  
29 pneumonitis (equine abortion) virus, Malignant catarrh virus  
30

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1 of cattle, Feline rhinotracheitis virus, Canine herpes  
2 virus, Epstein-Barr virus (associated with infectious  
3 mononucleosis and Burkitt lymphoma), Marek's disease virus,  
4 Sheep pulmonary adenomatosis (Jaagziekte) virus,  
5 Cytomegaloviruses, Adenovirus group, Human papilloma virus,  
6 Feline panleucopaenia virus, Mink enteritis virus, African  
7 horse sickness virus (9 serotypes), Blue tongue virus (12  
8 serotypes), Infectious pancreatic necrosis virus of trout,  
9 Fowl sarcoma virus (various strains), Avian leukosis virus  
10 (visceral, erythroblastic and myeloblastic), Osteopetrosis  
11 virus, Newcastle disease virus, Parainfluenza virus 1,  
12 Parainfluenza virus 2, Parainfluenza virus 3, Parainfluenza  
13 4, Mumps virus, Turkey virus, CANADA/58, Canine distemper  
14 virus, Measles virus, Respiratory syncytial virus,  
15 Myxovirus, Type A viruses such as Human influenza viruses,  
16 e.g., Ao/PR8/34, A1/CAM/46, and A2/Singapore/1/57; Fowl  
17 plaque virus; Type B influenza viruses, e.g., B/Lee/40;  
18 Rabies virus; Eastern equine encephalitis virus;  
19 Venezuelan equine encephalitis virus; Western equine  
20 encephalitis virus; Yellow fever virus, Dengue type 1 virus  
21 (=type 6), Dengue type 2 virus (=type 5); Dengue type 3  
22 virus; Dengue type 4 virus; Japanese encephalitis virus,  
23 Kyasanur Forest virus; Louping ill virus; Murray Valley  
24 encephalitis virus; Omsk haemorrhagic fever virus (types I  
25 and II); St. Louis encephalitis virus; Human rhinoviruses,  
26 Foot-and-mouth disease virus; Poliovirus type 1; Enterovirus  
27 Polio 2; Enterovirus Polio 3; Avian infectious bronchitis  
28 virus; Human respiratory virus; Transmissible  
29 gastro-enteritis virus of swine; Lymphocytic  
30

1 choriomeningitis virus; Lassa virus; Machupo virus; Pichinde  
2 virus; Tacaribe virus; Papillomavirus; Simian virus; Sindbis  
3 virus, and the like.

4 The lipid vesicle synthetic carriers of the  
5 present invention can be used to bind synthetic peptide  
6 analogues of bacteria, for example, leprosy, tuberculosis,  
7 syphilis and gonorrhea.

8 The lipid vesicle synthetic carriers of the  
9 present invention can also be used to bind synthetic peptide  
10 analogues of the following parasites: organisms carrying  
11 malaria (P. Falciparum, P. Ovace, etc.), Schistosomiasis,  
12 Onchocerca Volvulus and other filarial parasites,  
13 Trypanosomes, Leishmania, Chagas disease, amoebiasis,  
14 hookworm, and the like.

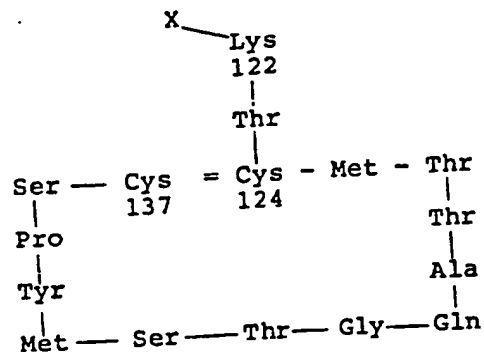
15 The lipid vesicle carriers of the present  
16 invention can be used to bind the novel peptides of the  
17 present invention corresponding to amino acid sequences in  
18 the pre-S region of HBsAg. The lipid vesicle carriers of  
19 the present invention can also be used to bind amino acid  
20 sequences in the S region, as well as other amino acid  
21 sequences for other virus, etc.

22 Amino acid sequences (corresponding to amino acids  
23 in the S region) which contains an antigenic determinant for  
24 hepatitis B surface antigen can be linked to the lipid  
25 vesicle carrier of the present invention. T.P. Hopp, "A  
26 Synthetic Peptide with Hepatitis B Surface Antigen  
27 Reactivity", Mol. Imm., 18, 9, 869-872, 1981, propose the  
28 following sequence corresponding to the S region of HBsAg:  
29 138 139 140 141 142 143 144 145 146 147 148 149  
30

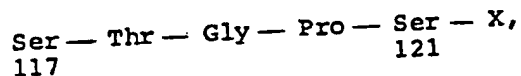
Cys Cys Thr Lys Pro Thr Asp Gly Asn Cys Thr Cys  
 Other peptides mimicking the antigenic determinant  
 of HBsAg (S region) include the following:

(1)

Peptide 1



Peptide 2 contains 5 additional amino acid residues:



G.R. Dreesman, Y. Sanchez, I. Ionescu-Matiu, J. T. Sparrow,  
 H. R. Six, D.L. Peterson, F.B. Hollinger and J.L. Melnick,  
 "Antibody to Hepatitis B Surface Antigen After A Single  
 Inoculation of Uncoupled Synthetic HBsAg Peptides", Nature,  
295, 158-160, 1982; and (2) the following peptides:

<u>POSITION</u>	<u>SEQUENCE</u>
48-81	Cys-Leu-Gly-Gln-Asn-Ser-Gln-Ser-Pro-Thr-Ser- Asn-His-Ser-Pro-Thr-Ser-Cys-Pro-Pro-Thr-Cys- Pro-Gly-Tyr-Arg-Trp-Met-Cys-Leu-Arg-Arg-Phe- Ile
2-16	Glu-Asn-Ile-Thr-Ser-Gly-Phe-Leu-Gly-Pro-Leu- Leu-Val-Leu-Gln-Cys

1           22-35           Leu Thr-Arg-Ile-Leu-Thr-Ile-Pro-Gln-Ser-Leu-  
2                           Asp-Ser-Trp-Cys  
3  
4           38-52           Ser-Leu-Asn-Phe-Leu-Gly-Gly-Thr-Thr-Val-Cys-  
5                           Leu-Gly-Gln-Asn  
6  
7           47-52           Val-Cys-Leu-Gly-Gln-Asn  
8  
9           95-109          Leu-Val-Leu-Leu-Asp-Tyr-Gln-Gly-Met-Leu-Pro-  
10                          Val-Cys-Pro-Leu  
11  
12           104-109          Leu-Pro-Val-Cys-Pro-Leu  
13  
14           R. Arnon, "Anti-influenza Response Achieved by Immunization  
15           With A Synthetic Conjugate", Proc. Natl. Acad. Sci. USA, 79,  
16           569-573, 1982. The peptide corresponds to the sequence  
17           serine-91 to leucine-108 of the amino acid chain of the  
18           virus.

19                       A peptide containing an amino acid sequence  
20           mimicking the antigenic determinant of polyoma virus medium  
21           size tumor antigen is Lys-Arg-Ser-Ars-His-Phe, G. Walter,  
22           M.A. Hutchinson, T. Hunter and W. Eckhart, "Purification of  
23           Polyoma Virus Medium-Size Tumor Antigen by Immunoaffinity  
24           Chromatography", Proc. Natl. Acad. Sci USA, 79, 4025-4029,  
25           1982.

26                       A peptide containing an amino acid sequence  
27           mimicking the antigenic determinant of poliovirus replicase  
28           antigen is as follows:  
29                       Tyr-Ser-Thr-Leu Tyr-Arg-Arg-Trp-Leu-Asp-Ser-Phe  
30                       450   461,

1 M. H. Baron and D. Baltimore, "Antibodies Against a  
2 Synthetic Peptide of the Poliovirus Replicase Protein:  
3 Reaction with Native, Virus-Encoded Proteins and Inhibition  
4 of Virus-Specific Polymerase Activities In Vitro". Jour.  
5 Virology, 43, 3969-3978, 1982.

6 Peptides containing an amino acid sequence  
7 mimicking the antigenic determinant of simian virus 40 large  
8 tumor antigen are as follows:

9 Met-Asp-Lys-Val-Leu-Asn-Arg and

10 Lys-Pro-Pro-Thr-Pro-Pro-Pro-Glu-Pro-Glu-Thr,

11 G. Walter, K.H. Scheidtmann, A. Carbone, A.P. Laudano and  
12 R.A. Lerner, N. Green, H. Alexander, F.-T. Liu, J.G.  
13 Sutcliffe and T.M. Shinnick, "Chemically Synthesized  
14 Peptides Predicted From the Nucleotide Sequence of the  
15 Hepatitis B Virus Genome Elicit Antibodies Reactive With the  
16 Native Envelope Protein of Dane Particles", Proc. Natl.  
17 Acad. Sci. USA, 78, 6, 3403-3407, 1981.

18 A peptide containing an amino acid sequence  
19 mimicking the antigenic determinant of retrovirus R antigen  
20 is as follows:

21 Leu-Thr-Gln-Gln-Phe-His-Gln-Leu-Lys-Pro

22 Ile-Glu-Cys-Glu-Pro,

23 J.G. Sutcliffe, T.M. Shinnick, N. Green, F.-T. Liu, H.L.  
24 Niman and R.A. Lerner, "Chemical Synthesis of A Polypeptide  
25 Predicted From Nucleotide Sequence Allows Detection Of A New  
26 Retroviral Gene Product", Nature, 287, 1980.

27 A peptide containing an amino acid sequence  
28 mimicking the antigenic determinant of avian sarcoma virus  
29 antigen is as follows:  
30

1 Glu-Asp-Asn-Glu-Tyr-Thr-Ala-Arg-Gln-Gly,

2 T.W. Wong and Alan R. Goldberg, "Synthetic Peptide Fragment  
3 Of src Gene Product Inhibits the src Protein Kinase and  
4 Cross reacts Immunologically With Avian onc Kinases and  
5 Cellular Phosphoproteins", Proc. Natl. Acad. USA, 78, 12,  
6 7412-7416, 1981.

7 Peptides containing an amino acid sequence  
8 mimicking the antigenic determinant of foot-and-mouth  
9 disease virus antigen are as follows:

10 141

11 Val Pro Asn Leu Arg Gly Asp Leu Gly Val

12 Leu Ala Gly Lys Val Ala Arg Thr Leu Pro 160

13 and

14 201

15 His Lys Gln Lys Ile Val Ala Pro Val Lys Gln

16 Thr Leu,

17 J.L. Bittle, R.A. Houghten, H. Alexander, T.M. Shinnick,  
18 J.G. Sutcliffe, R.A. Lerner, D.J. Rowlands and F. Brown,  
19 "Protection Against Foot-And-Mouth Disease By Immunization  
20 With A Chemically Synthesized Peptide Predicted From the  
21 Viral Nucleotide Sequence", Nature, 298, 30-33, 1982.

22 A peptide containing an amino acid sequence  
23 mimicking the antigenic determinant of hemagglutinin X-31  
24 (H3N2) influenza virus antigen is as follows:

25 123 125

26 Glu-Gly-Phe-Thr-Trp-Thr-Gly-

27 130

28 Val-Thr-Gln-Asn-Gly-Gly-Ser-

29 140

30 Asp Ala-Cys-Lys-Arg-Gly-Pro-

145

Gly-Ser-Gly-Phe-Phe-Ser-Arg-

150



151  
Leu,

D.C. Jackson, J.M. Murray, D.O. White, C.N. Fagan and G.W. Tregear, "Antigenic Activity of a Synthetic Peptide Comprising the 'Loop' Region of Influenza Virus Hemagglutinin", Virology, 120, 273-276, 1982.

A peptide containing an amino acid sequence mimicking the antigenic determinant of hemagglutinin of type A H3N2 influenza virus antigen was synthesized by G.M. Muller, M. Shapira and R.F. Doolittle, "Antibodies Specific for the Carboxy- And Amino- Terminal Regions of Simian Virus 40 Large Tumor Antigen", Proc. Natl. Acad. Sci USA, 77, 9, 5179-5200, 1980.

A peptide containing an amino acid sequence mimicking the antigenic determinant of influenza virus strain 3QB antigen is Ile<sub>1</sub> Val<sub>1</sub> Asx<sub>2</sub> Thr<sub>1</sub> Ser<sub>2</sub> Glx<sub>2</sub> Pro<sub>1</sub> Gly<sub>3</sub> Ala<sub>1</sub> Leu<sub>1</sub> Lys<sub>1</sub>, A. Aitken and C. Hannoun, "Purification of Haemagglutinin and Neuraminidase from Influenza Virus Strain 3QB and Isolation of a Peptide From an Antigenic Region of Haemagglutinin", Eur. J. Biochem, 107, 51-56, 1980.

Peptides containing an amino acid sequence mimicking the antigenic determinant of diptheria antigen are given as follows:

Natural DT Loop

-Cys-Ala-Gly-Asn-Arg-Val-Arg-Arg-Ser-Val-  
186 190 195

Gly-Ser-Ser-Leu-Lys-Cys-  
201

Synthetic Peptide

Tetradecapeptide

Gly(188)---Cys-(201)

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1 Hexadecapeptide Cys(186)---Cys-(201)

2 Octadecapeptide Ala-Ala-Cys(186)---Cys-(201)

3 F. Audibert, M. Jolivet, L. Chedid, R. Arnon and M. Sela,  
4 "Successful Immunization With a Totally Synthetic Diphtheria  
5 Vaccine", Proc. Natl. Acad. Sci. USA, 79, 5042-5046, 1982.

6 A peptide containing an amino acid sequence  
7 mimicking the antigenic determinant of Streptococcus  
8 pyogenes M antigen is as follows:

9  
10 Asn-Phe-Ser-Thr-Ala-Asp-Ser-Ala-Lys  
11 10 15  
12 Ile-Lys-Thr-Leu-Glu-Ala-Glu-Lys-Ala-Ala-  
13 20 25  
14 Leu-Ala-Ala-Arg-Lys-Ala-Asp-Leu-Glu-Lys-  
15 30 35  
16 Ala-Leu-Glu-Gly-Ala-Met

17 E.H. Beachey, J.M. Seyer, D.B. Dale, W.A. Simpson and A.H.  
18 Kang, "Type-Specific Protective Immunity Evoked by Synthetic  
19 Peptide of Streptococcus Pyogenes M Protein", Nature, 292,  
20 457-459, 1981.

21 The lipid vesicle carrier of the present invention  
22 can thus be utilized to bind with any amino acid sequence  
23 which includes the antigenic determinant for a specific  
24 antigen.

25 The lipid vesicle carriers of the present  
26 invention can also be used to bind with enzymes.

27 The present invention is also directed to  
28 diagnostic tests for direct detection of HBV antigens and  
29 HBV antibodies.

30 In order to detect HBV antigens containing  
proteins coded for by the pre-S gene in sera of HBV-infected

1 animals such as humans, radioimmunoassay (RIA) or  
2 enzyme-linked immunosorbent assay (ELISA) can be employed.

3 One test for detecting HBV antigens according to  
4 the present invention is as follows:

5 (1) a solid substrate containing binding sites  
6 thereon, e.g., polystyrene beads, is coated with antibodies  
7 to a peptide having an amino acid chain corresponding to at  
8 least six amino acids within the pre-S gene coded region of  
9 the envelope of HBV, the peptide free of an amino acid  
10 sequence corresponding to the naturally occurring proteins of  
11 HBV;

12 (2) the coated beads are then washed with, for  
13 example, tris buffered saline, to remove excess antibody;

14 (3) the beads are then contacted with a protein-  
15 containing solution, such as bovine serum albumin (BSA) or  
16 gelatin to saturate protein binding sites on the beads (to  
17 prevent or reduce non-specific binding) - a convenient  
18 concentration of such protein-containing solution can be  
19 employed such as 1 mg/ml to 50 mg/ml;

20 (4) beads are then washed to remove excess BSA or  
21 gelatin;

22 (5) the beads are then incubated with samples  
23 suspected to contain HBV or HBsAg (normal sera is utilized  
24 as a control);

25 (6) the beads are then washed with a solution,  
26 e.g., tris buffered saline solution, and mixed with a  
27 radiolabeled antibody, e.g.,  $I^{125}$  labeled antibody (antibody  
28 to either the peptide or to HBsAg);

29 (7) the beads are then incubated;  
30

1           (8) the beads are then washed and counted in a  
2 gamma counter.

3           If the specimens have counts at least 2.1 times  
4 higher than counts of the control, then the specimens are  
5 positive.

6           The pre-S gene coded peptides according to the  
7 present invention can be employed as a diagnostic tool to  
8 detect antibodies to the pre-S region of HBV in a given  
9 sample. The pre-S gene coded peptide, for example, pre-S  
10 (120-145), pre-S (12-32), pre-S (32-53), or pre-S (117-134),  
11 pre-S(1-21), pre-S(94-117), pre-S(153-171), pre-S(32-53) and  
12 pre-S(57-73), is adsorbed on a solid substrate, containing  
13 binding sites thereon for example, polystyrene beads. The  
14 substrate is thereafter contacted with a substance (protein  
15 containing solution), for example, gelatin BSA or powdered  
16 milk, to saturate the binding sites thereon. Thereafter,  
17 the substrate is washed with a buffered solution and  
18 thereafter the buffer is removed. A specimen, e.g., human  
19 sera diluted with animal sera is added to the substrate.  
20 The resultant mass is then incubated and washed.  
21 Thereafter, radiolabeled, e.g., iodinated, e.g., I<sup>125</sup>,  
22 antibodies to human IgG or IgM is added to the mass. The  
23 resultant mass is then washed and counted, e.g., in a  
24 gamma-counter. If the count is higher than a count  
25 performed on a normal sera control, the specimen contains  
26 antibodies to the pre-S region of HBV.  
27

28           It is believed that the above procedure for  
29 detection of antibodies to the pre-S region of HBV can be  
30

1 applied as a diagnostic tool in detecti~~ng~~ hepatitis B virus  
2 infection.

3 The pre-S protein moiety appears to be directly  
4 involved in attachment of HBV to liver cells of the host.  
5 Similar proteins are likely to be involved in the attachment  
6 of other viruses, the target of which is the liver. For  
7 this reason, synthetic peptides corresponding to the pre-S  
8 protein, as well as antibodies to them, could serve as the  
9 basis for diagnostic assays of and vaccines against other  
10 hepatitis viruses reacting with the same liver receptors as  
11 does hepatitis B virus.

12 In the above described procedures involving  
13 radioimmunoassay (RIA), an enzyme linked antibody can  
14 replace the radiolabeled antibody and ELISA techniques can  
15 be performed. Furthermore, fluorescence techniques can be  
16 employed in place of RIA or ELISA.

17 The labelling ("marking") of one of the reaction  
18 components can be brought about by use of a "marker" or  
19 "marker substance" such as by incorporation of a radioactive  
20 atom or group, or by coupling this component to an enzyme, a  
21 dyestuff, e.g., chromophoric moiety or a fluorescent group.

22 The components concerned are preferably labelled  
23 by coupling to an enzyme, since the estimation of this is  
24 much simpler than for example, the estimation of  
25 radioactivity, for which special apparatus is necessary.

26 The enzymes used are preferably those which can be  
27 colorimetrically, spectrophotometrically, or  
28 fluorimetrically determined. Non-limiting examples of  
29 enzymes for use in the present invention include enzymes  
30

from the group of oxidoreductases, such as catalase,  
peroxidase, glucose oxidase, beta-glucuronidase,  
beta-D-glucosidase, beta-D-galactosidase, urease and  
galactose oxidase.

The coupling of the enzyme and the immunological  
component can be brought about in a known way, for example,  
by the formation of an amide linkage by methods known from  
peptide chemistry.

The labelling with a radioactive isotope can also  
be performed in a known way. Isotopes useful for labelling  
are predominantly  $I^{125}$ ,  $I^{131}$ ,  $C^{14}$ , and  $H^3$ .

The incubation steps utilized in carrying out the  
above procedures can be effected in a known manner, such as  
by incubating at temperatures of between about 20°C and  
about 50°C for between about 1 hour and about 48 hours.

Washings as described above are typically effected  
using an aqueous solution such as one buffered at a pH of  
6-8, preferably at a pH of about 7, employing an isotonic  
saline solution.

The present invention also concerns diagnostic  
test kits for conducting the above-described methods for  
detecting antigens and antibodies.

A diagnostic test kit according to the present  
invention for detecting antigens coded for the pre-S gene of  
HBV in a test sample, would include the following:

a. a solid substrate coated with antibodies to a  
peptide having an amino acid chain corresponding to at least  
six consecutive amino acids within the pre-S gene coded  
region of the envelope of HBV, the peptide free of an amino

1 acid sequence corresponding to the naturally occurring  
2 proteins of HBV,

3 b. a protein-containing solution to saturate  
4 protein binding sites on the solid substrate, and

5 c. a given amount of radiolabeled antibody, such  
6 antibody to either the peptide or HBsAg.

7 A diagnostic test kit according to the present  
8 invention for detecting antibodies to the pre-S region of  
9 hepatitis B virus in a test sample, would include the  
10 following:

11 a. a solid substrate having adsorbed thereon a  
12 peptide having an amino acid chain corresponding to at least  
13 six consecutive amino acids within the pre-S gene coded  
14 region of the envelope of HBV, the peptide free of an amino  
15 acid sequence corresponding to the naturally occurring  
16 proteins of HBV, the substrate being exposed to a  
17 protein-containing solution to saturate protein binding  
18 sites on the solid substrate, and

19 b. a given amount of radiolabeled antibodies to  
20 human IgG or IgM.

21 Radiolabeled antibodies used in the  
22 above-described test kits can be packaged in either solution  
23 form, or in lyophilized forms suitable for reconstitution.

24 In the above test kits, enzyme or fluorescent  
25 labelled antibodies can be substituted for the described  
26 radiolabeled antibodies.

27 The above described process and test kit for  
28 detection of antibodies to the pre-S region of hepatitis B  
29 virus can be utilized in many applications, such as  
30

- 1                   (1) detecting HBV infection in a patient by  
2                   taking serum from the patient and applying the above  
3                   described test or using the above described test kit; and  
4                   (2) predicting recovery from HBV infection by  
5                   taking serum from an infected patient and applying the above  
6                   described antibody detection procedures.

7                   The above described test procedure and test kit  
8                   for antibody detection can be used for making qualitative  
9                   comparisons between different HBV vaccines by taking serum  
10                  from vaccinated patients and then utilize the  
11                  above-described test procedure or kit for antibody  
12                  detection. In general all known immunoassays using this  
13                  antigen as reagent can be performed using the synthetic  
14                  peptide of this invention. Generally all known immunoassays  
15                  using antibody containing serum or reagents can be performed  
16                  using antibody serum produced through the use of a synthetic  
17                  peptide of this invention. These immunoassays included all  
18                  those disclosed by Langone and Van Vunakis, Methods of  
19                  Enzymology, Academic Press, Volumes 70, 73 and 74. Those  
20                  assays disclosed in the disclosures of the following U.S.  
21                  Patents: 4,459,359; 4,343,896; 4,331,761; 4,292,403;  
22                  4,228,240; 4,157,280; 4,152,411; 4,169,012; 4,016,043;  
23                  3,839,153; 3,654,090 and Re 31,006 and volumes 70, 73 and 74  
24                  of Methods of Enzymology are incorporated herein by  
25                  reference.  
26

27                  A hepatitis B vaccine can be prepared by directly  
28                  using a conjugate of a lipid vesicle and a peptide  
29                  containing an amino acid chain corresponding to at least six  
30                  consecutive amino acids within the pre-S gene coded region



1 of the surface antigen of hepatitis B virus in an  
2 appropriate buffer. The conjugate having peptide in the  
3 appropriate concentration can be used as a vaccine with or  
4 without an adjuvant, such as, e.g., aluminum hydroxide or  
5 others.

6 The active component of the vaccine can be  
7 employed with a physiologically acceptable diluent (medium),  
8 e.g., phosphate buffered saline. Generally speaking, the  
9 synthetic peptide concentration in a physiologically  
10 acceptable medium will be between approximately less than 1  
11 miligram and more than 10 micrograms per dose.

12 The vaccine can be prepared and used in the same  
13 general manner as disclosed in U.S.P. 4,118,479, the entire  
14 contents of which are incorporated by reference herein.

15 The vaccine can be administered by subcutaneous,  
16 intradermal or intramuscular injection. While the preferred  
17 route would depend upon the particular vaccine, it is  
18 believed that intramuscular injection will be generally  
19 suitable. Frequency of administration will vary depending  
20 upon the vaccine. Generally speaking, the vaccine will be  
21 administered in two doses about one month apart followed by  
22 a booster at six months to one year after primary  
23 immunization. The subsequent doses or the booster will  
24 depend on the level of antibody in the blood as a result of  
25 the initial immunization, and in certain instances may be  
26 unnecessary.

27 The hepatitis vaccine of the present invention is  
28 recommended for all persons at risk of developing hepatitis  
29 B infection and particularly those at especially high risk  
30

1 such as patients and staff on hemodialysis unit, n 'ical  
2 , personnel, persons of tropical populations and those  
3 visiting the tropics. In the case of tropical populations,  
4 particularly in Africa, Asia, the Mediterranean region and  
5 South America, where high incidence of hepatitis B  
6 infections has been consistently observed, the vaccine  
7 should be administered sufficiently early in life to prevent  
8 acquisition of chronic carrier state infection which tend to  
9 occur in these regions within the first five years of life.  
10 In fact, the vaccine is expected to be useful for all  
11 persons not already protected against hepatitis B infections  
12 as a result of prior immunity.  
13

14 In order to more fully illustrate the nature of  
15 the invention and the manner of practicing the same, the  
16 following non-limiting examples are presented:

#### 17 EXAMPLES

##### 18 Example 1

##### 19 SDS-Polvacrylamide Gel Electrophoresis Of HBsAg.

20 About 20 and 200 ug, respectively, of HBsAg were  
21 separately electrophoresed for silver staining and transfer  
22 to nitrocellulose, respectively. Before electrophoresis,  
23 HBsAg was treated for 30 minutes at 37°C with  
24 2-mercaptoethanol and NaDodSO<sub>4</sub> (10 mg/ml each in 8 M urea,  
25 0.0625 M Tris, pH 7.2). Similar results were obtained with  
26 HBsAg alkylated with iodoacetate after reduction. HBsAg was  
27 purified and radiolabeled as described (A.R. Neurath, N.  
28 Strick, C.Y. Huang, Intervirology, 10, 265 (1978)).

29 SDS-Polyacrylamide gel electrophoresis  
30 ("SDS-PAGE") was carried out following published procedures.

1 See V.K. Laemmli, Nature (London), 227, 680 (1970).  
2 However, in order to maintain proteins in fully denaturated  
3 form, 8M urea was utilized in the running buffers in  
4 electrophoresis.

5 Polypeptides separated by SDS-PAGE were  
6 transferred to nitrocellulose using the TE 42 Transphor unit  
7 9 (Hoefer Scientific Instruments, San Francisco, California)  
8 following the procedure recommended by the manufacturer. The  
9 transferred proteins were tested for determinants reacting  
10 with antibodies to intact HBsAg (anti-HBs) using  
11  $^{125}\text{I}$ -labeled human anti-HBs supplied as part of a commercial  
12 test kit (Abbott Laboratories, North Chicago, Illinois) as  
13 described (J.C. McMichael, L.M. Greisiger, L. Millman, J.  
14 Immunol. Meth., 45, 79, (1981)).

15 From the 20ug sample gel, separated HBsAg  
16 polypeptides (their  $M_r$  given in kilodaltons) were stained by  
17 silver in situ (J.H. Morrissey, Anal. Biochem, 117, 307,  
18 (1981)), (see Fig. 1, Panel a) to yield two major and  
19 several minor polypeptides as expected. The separated  
20 polypeptides from the other 200  $\mu\text{g}$  sample gel was then  
21 electrophoretically transferred to nitrocellulose, reacted  
22 (probed) with  $^{125}\text{I}$ -labeled antibodies to intact HBsAg (anti  
23 HBs) and submitted to autoradiography (Fig. 1b).

24 Surprisingly, the 33 and 36 kilodalton (P33 and  
25 P36), rather than the two most abundant polypeptides reacted  
26 preferentially with anti-HBs (Fig. 1, Panel b). This  
27 suggested the presence of disulfide bond independent  
28 antigenic determinants reacting with anti-HBs on amino acid  
29 sequences which are not coded for by the S-gene of HBV DNA.  
30

P33 and P36 contain the sequence corresponding to the product of the S-gene and additional 55 residues at the amino-terminal part starting with Met at position 120 in the pre-S gene region (See Fig. 2).

#### Example 2

#### Synthesis Of A Peptide Mimicking Antigenic Determinants Corresponding To Residues 120-145 Of The Pre-S Gene Product

The location of antigenic determinants on proteins may be predicted from computing the relative hydrophilicity along the amino acid sequence. See T.P. Hopp, K.R. Woods, Proc. Natl. Acad. Sci. USA, 78, 3824 (1981) and J. Kyte, R.F. Doolittle, J. Mol. Biol., 157, 105 (1982).

Results of such computation (J. Kyte et al supra) for the translation product of the pre-S region are shown in Fig. 3 and suggest the location of antigenic determinants in the sequence to the right from Met 120 within residues 120-140. The segment corresponding to residues 120-145 (Fig. 2) (pre-S 120-145, subtype adw<sub>2</sub>) was selected for synthesis.

A C-terminal Cys(-SH containing) residue was added to allow unambiguous conjugation to carrier molecules and affinity matrices, while leaving the N-terminal unblocked as it may be in the intact protein. The molecule contains one Tyr and can therefore be radiolabeled. The Tyr could also be used for conjugation, although it might be a part of the antigenic determinant.

The peptide was synthesized by an accelerated version of stepwise solid phase peptide synthesis on the benzhydrylamine-type resin of Gaehde and Matsueda (Int. J.

1 Peptide Protein Res., 18, 451, (1981)) using  
2 Boc-NH-CH(phenyl)-phenyl-OCH<sub>2</sub>COOH to derivatize NH<sub>2</sub>CH<sub>2</sub>-Resin  
3 (A.R. Mitchell, S.B.H. Kent, M. Engelhard and R.B.  
4 Merrifield, J. Org. Chem., 43, 2845-2852, (1978)). After the  
5 Cys was coupled, the protected peptide chain was assembled  
6 according to the following protocol:

7 1. Deprotection: 65% v/v trifluoroacetic acid in  
8 dichloromethane, 1x10 minutes;

9 2. Wash: a flowing stream of dichloromethane was  
10 run over the resin under suction from an aspirator for 20  
11 seconds;

12 3. Neutralization: 10% v/v diisopropylethylamine  
13 in dichloromethane, 2x1 minutes;

14 4. Wash: a flowing stream of dichloromethane was  
15 run over the resin under suction from an aspirator for 20  
16 seconds;

17 5. Coupling: 2 mmol tert.Boc-L-amino acid in 2ml  
18 dichloromethane was added to the neutralized resin followed  
19 immediately by 1mmol dicyclohexylcarbodiimide in 2ml  
20 dichloromethane; after 10 minutes a sample of resin  
21 (approximately 5mg) was taken for determination of coupling  
22 yield by quantitative ninhydrin, and 10ml dimethylformamide  
23 was added and the coupling continued. (Asn and Gln were  
24 coupled in the presence of hydroxybenzotriazole).

25 6. After the ninhydrin determination of a  
26 satisfactory coupling, the resin was washed as in step 4,  
27 above. For the addition of subsequent residues, the cycle  
28 was repeated. If recoupling was necessary, steps 3-5 were  
29 repeated. The synthesis was performed on a 0.5mmol scale  
30

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1 0.5gram aminomethyl-resin of 1mmol/g loading). All volumes  
2 were 10ml except where noted.

3 Protected amino acid derivatives used were  
4 N-alpha-tert.butyloxycarbonyl protected and side chain  
5 protected as follows: Arg(N<sup>G</sup>Tosyl); Cys(4MeBzl); Tyr(BrZ);  
6 Asp(OBzl); Thr(Bzl); His(ImTosyl). Met and Trp were  
7 unprotected on the side chains. In another synthesis,  
8 otherwise identical, use of His(ImDNP) and Trp(InFormyl)  
9 gave purer product.

10 Assembly of the peptide chain was monitored by the  
11 quantitative ninhydrin reaction (V.K. Sarin, S.B.H. Kent,  
12 J.P.Tam, R.B. Merrifield, Anal. Biochem, 117, 147-157,  
13 (1981)) and was without difficulty except for the addition  
14 of the histidine residue which was 10% incomplete despite  
15 repeated couplings, presumably due to an impure amino acid  
16 derivative. After assembly of the protected peptide chain,  
17 the N-terminal Boc group was removed by trifluoroacetic acid  
18 treatment and the resin neutralized as in steps 1-4 above.  
19 Then the peptide was cleaved and deprotected by a 1 hour  
20 treatment at 0°C with HF containing 5% v/v p-cresol and 5%  
21 v/v p-thiocresol to give the desired peptide as the  
22 C-terminal cysteinamide. Where His(ImDNP) was used, the DNP  
23 was removed by treatment with phenylphenol prior to HF  
24 cleavage. Where Trp (InFormyl) was used, HF conditions were  
25 adjusted to remove the Formyl group; either HF containing  
26 10% anisole and 5% 1,4-butanedithiol, or HF containing  
27 p-cresol and 5% 1,4-butanedithiol. The product was  
28 precipitated and washed by the addition of ether, then  
29 dissolved in 5% v/v acetic acid in water and lyophilized to  
30

1 give a fluffy white solid  
2 Quantitative Edman degradation (H.D. Niall, G.W.  
3 Tregear, J. Jacobs, Chemistry and Biology of Peptides, J.  
4 Meienhofer, Ed (Ann Arbor Press, Ann Arbor, MI, 1972), pp.  
5 659-699) of the assembled peptide-resin revealed a high  
6 efficiency of chain assembly (S.B.H. Kent, M. Riemen, M.  
7 LeDoux, R.B. Merrifield, Proceedings of the Fourth  
8 International Symposium on Methods in Protein Sequence  
9 Analysis, M. Elzinga, Ed. (Humana, Clifton, New Jersey,  
10 1982), pp. 626-628) which proceeded at a  $\geq 9.7$  percent  
11 efficiency at each step, except for histidine at sequence  
12 position pre-S 128. HPLC of the peptide cleaved off the  
13 resin revealed a single major peak corresponding to  
14 approximately 85 percent of peptide material absorbing light  
15 at 225 nm.

#### 16 Examples 3-6

17 Immunologic Properties Of A Peptide Mimicking  
18 Antigenic Determinants Corresponding To Residues 120-145 of  
19 the Pre-S Gene Product (pre-S 120-145)  
20

#### 21 Example 3

##### 22 Immunization

23 Immunization of rabbits with either free or  
24 carrier-bound pre-S 120-145 (subtype adw<sub>2</sub>) were conducted  
25 and resulted in an antibody response in all animals against  
26 both the homologous peptide and HBsAg (Fig. 4).  
27

28 The peptide corresponding to the amino acid  
29 sequence 120-145 (pre-S 120-145) of the pre-S region of HBV  
30 DNA (subtype adw<sub>2</sub>; P. Valenzuela, P. Gray, M. Quiroga, J.

1 Zaldivar, H.M. Goodman, W.J. Rutter, Nature (London), 280,  
2 815, (1979)) containing an additional Cys residue at the  
3 C-terminal, added for convenience of coupling to carriers,  
4 was synthesized by an improved solid phase technique (S.B.H.  
5 Kent, Biomedical Polymers, E.P. Goldberg, A. Nakajima, Eds.  
6 (Academic, New York, 1980), pp. 213-242; A.R. Mitchell,  
7 S.B.H. Kent, M. Engelhard, R.B. Merrifield, J. Org. Chem.  
8 43, 2845, (1978); and S. Mojsov, A.R. Mitchell, R.B.  
9 Merrifield, J. Org. Chem., 45, 555 (1980).

10 For immunoassays and linking to carriers the  
11 peptide was treated with 2-mercaptoethanol and separated  
12 from low  $M_r$  components by chromatography on Sephadex G-10  
13 (A.R. Neurath, S.B.H. Kent, N. Strick, Proc. Natl. Acad.  
14 Sci. USA, 79, 7871 (1982)).

15 Groups of two to three rabbits were immunized with  
16 either free pre-S 120-145 or with the peptide linked to  
17 cysteine-activated liposomes containing stearylamine,  
18 dilauroyl lecithin and cholesterol which had been fixed with  
19 glutaraldehyde, and either did or did not have attached RAT  
20 groups for enhancing antibody responses to haptens (A.R.  
21 Neurath, S.B.H. Kent, N. Strick, J. Gen. Virol., in press  
22 (1984)). The immunization schedule involving the use of  
23 complete and incomplete Freund's adjuvant was the same as  
24 described (Neurath, Kent, Strick, et al (1984) supra).  
25 Antibodies to HBsAg in sera of rabbits immunized with pre-S  
26 120-145 were tested by a double-antibody radioimmunoassay  
27 (RIA) using HBsAg-coated polystyrene beads and  $^{125}\text{I}$ -labeled  
28 anti-rabbit IgG (Neurath, Kent, Strick, et al (1984) supra).  
29  
30



Antibodies to the homologous peptide were tested by a similar test except that 2.5 mg of a cellulose-peptide conjugate were used instead of coated beads. This conjugate was prepared in the following way: 0.5 g of sulfhydryl cellulose, prepared as described (P.L. Feist, K.J. Danna, Biochemistry, 20, 4243 (1981)), were suspended in 5 ml 0.1 M sodium acetate, pH 5, and mixed with 2.5 ml of 0.25 M N-N'-p-phenylenedimaleimide in dimethylformamide for one hour at 30°C and then washed with 0.1 M phosphate-10mM EDTA, pH 7.0. The cellulose derivative was suspended in 10 ml of the latter buffer containing 5 mg of pre-S 120-145 and mixed for at least sixteen hours at 20°C. The cellulose derivative was extensively washed and suspended in 0.14 M NaCl-10 mM Tris-3 mM NaN<sub>3</sub> (TS). The final preparation contained 8 mg of pre-S 120-145 per g of cellulose.

#### Example 4

Radioimmunoassays were conducted with several dilutions of a serum from one of the rabbits immunized with pre-S 120-145 linked to liposomes (See Fig. 5).

Antibodies were still detectable when the antisera were diluted up to  $1.6 \times 10^5$ -fold (Fig. 5).

Pre-S 120-145 or anti-pre-S 120-145 inhibited the reaction between <sup>125</sup>I-labeled anti-HBs and P33 (P36). <sup>125</sup>I-labeled HBsAg was immunoprecipitated with anti-pre-S 120-145 at all dilutions positive by RIA (Fig. 5). HBV particles reacted with anti-pre-S 120-145 as determined by detection of HBV-DNA within the immune complexes and by

1 electron microscopy (A.R. Neurath, N. Strick, L. Baker, S.  
2 Krugman, Proc. Nat. Acad. Sci. USA, 79, 4415 (1982)).  
3

#### 4 Example 5

##### 5 Anti-Peptide Antibody as A Specific Probe for 6 Detection of P33 and P36

7 Anti-pre-S 120-145 was reacted with P33 and P36.  
8 HBsAg polypeptides separated by SDS-PAGE run in urea were  
9 transferred to nitrocellulose, reacted with anti-pre-S  
10 120-145 diluted 1/80 in TS containing 10 mg/ml of bovine  
11 serum albumin and 2.5 mg/ml of gelatine (TS-BG) for five  
12 hours at 20°C. To detect bound IgG, the nitrocellulose sheet  
13 was washed and exposed to  $^{125}\text{I}$ -labeled protein A (0.4  $\mu\text{C}/100$   
14 ml TS-BG) for five hours at 20°C. For further details see  
15 Fig. 1. In Fig. 6, arrows indicate the positions of P33 and  
16 P36. The top arrow (corresponding to a molecular weight of  
17 66 kilodaltons) indicates another protein reacting with  
18 anti-pre-S 120-145, possibly corresponding to a dimer of  
19 P33.  
20

#### 21 Example 6

##### 22 Development Of A Diagnostic Test For The 23 Detection Of Antigens Coded For By The Pre-S Gene In Sera 24 Of HBV-Infected Individuals

25 Fig. 7 shows the results of a diagnostic test  
26 based on polystyrene beads coated with anti-pre-S 120-145.  
27

28 Serial dilutions of an HBsAg-positive serum in a  
29 mixture of normal human and rabbit serum each diluted 1/10  
30 in TS were tested.  $^{125}\text{I}$ -labeled human anti-HBs (Abbott

1 Laboratories) was used in the test performed essentially as  
 2 described for the AUSRIA II diagnostic kit (Abbott  
 3 Laboratories). Results are expressed as RIA ratio units,  
 4 determined by dividing cpm corresponding to positive samples  
 5 by cpm corresponding to positive sample by cpm  
 6 corresponding to normal serum controls. The endpoint titer  
 7 corresponds to the highest dilution at which the RIA ratio  
 8 was 2.1 (broken line). The endpoint titer of the serum as  
 9 determined by the AUSRIA test was approximately  $1/10^6$ .  
 10 Negative results were obtained with control beads coated  
 11 with normal rabbit IgG.

12 Similar results were obtained with sera containing  
 13 HBsAg subtypes ad and ay, indicating that the synthetic  
 14 peptide with the sequence corresponding to subtype adw (Fig.  
 15 2) carried common group-specific antigenic determinants.

#### 17 Example 7

#### 18 Synthesizing and Testing 19 S(135-155) Derivatives

20 Each of the conjugates ((1) to (26)) of S(135-155)  
 21 listed in Table 1, except conjugate 3, was mixed 1:1 with  
 22 complete Freund's adjuvant and injected into two New Zealand  
 23 White rabbits (65 to 160  $\mu$ g of peptide per rabbit). The  
 24 rabbits were further injected at biweekly intervals with  
 25 equal doses of conjugates in incomplete Freund's adjuvant  
 26 (not used for conjugate 3). Blood specimens were taken two  
 27 weeks after each injection.

28 To prepare conjugates 1, and 4-8 (Table 1), 1 mg  
 29 quantities of peptide 309-329 of the env gene product  
 30 (S(135-155)) were activated with a two times molar excess o

1 N-ethyl-N' (dimethyl-aminopropyl) carbodiimide (EDAC) and  
2 N-hydroxy-benzotriazole (NHBT) and subsequently linked to  
3 equimolar quantities of poly-D-lysine and diaminoalkanes  
4 (from Fluka AG, Buchs, Switzerland), respectively, as  
5 described (Arnon, R., Sela, M., Parant, M. and Chedid., L.,  
6 "Antiviral Response Elicited By A Completely Synthetic  
7 Antigen With Built-In Adjuvanticity", Proceedings of The  
8 National Academy of Science USA, 77,6769-6772, (1980)). To  
9 prepare conjugates 2 and 3, 1 mg quantities of each  
10 EDAC-activated S(135-155) and MDP (Calbiochem, San Diego,  
11 California) were linked to 10 mg of poly-D-lysine. Peptide  
12 309-329 of the env gene product (800µg) was oxidized with  
13 ferricyanide (Dreesman et al, 1982 supra), activated with  
14 EDAC as above and linked to 4 mg of LPH. Chromatography on  
15 Sephadex G-25 indicated complete linking of the peptide to  
16 LPH (conjugate 9). The oxidized, EDAC-activated peptide (1  
17 mg) was also conjugated to 1 mg of polyvaline in a  
18 suspension of 2.5 ml of 1 M NaHCO<sub>3</sub>, pH 8.5, and 10 ml of  
19 CHCl<sub>3</sub>. The interphase and aqueous phase after centrifugation  
20 was used for immunization (conjugate 10).  
21

22 Liposomes were prepared by the method of Oku, N.  
23 Scheerer, J.F., and MacDonald, R.C., "Preparation of Giant  
24 Liposomes", Biochimica et Biophysica Acta, 692, 384-388  
25 (1982). Stearylamine, dilauroyl lecithin and cholesterol  
26 were dissolved in glucose-saturated ethanol at final  
27 concentrations of 10, 23 and 1.43 mg/ml, respectively. For  
28 some liposome preparations, the concentration of dilauroyl-  
29 lecithin was decreased to 17.5 mg/ml and sphingomyelin was  
30 added (10 mg/ml). Other preparations contained as an

1 additional component lipid A (420µg/ml; Calbiochem). The  
2 solutions were dialyzed against 0.1 M NaCHO<sub>3</sub>, pH 8.5, in  
3 dialysis bags with a molecular weight cut-off of 10<sup>3</sup> daltons  
4 for at least sixteen hours. The liposomes were treated for  
5 approximately six hours with glutaraldehyde (final  
6 concentration 30 mg/ml), mixed with 0.5 volumes of 33.9%  
7 (w/w) sodium diatrizoate, floated four times into 1 M NaCHO<sub>3</sub>  
8 by centrifugation for ten minutes at 10,000 rpm, and reacted  
9 with 0.84 to 1 mg of peptide 309-329 of the env gene product  
10 per 10 mg stearylamine overnight at 20°C. The linking of  
11 peptide 309-329 of the env gene product to liposomes under  
12 these conditions was complete. Some preparations were  
13 reacted additionally with 7.5 mg of RAT (Biosearch, San  
14 Rafael, California) per 10 mg of stearylamine for six hours  
15 at 20°C. The liposomes were floated three times into 0.14 M  
16 NaCl, 0.01 Tris-HCl-0.02% NaN<sub>3</sub> (TS) and dialyzed against  
17 TS-10<sup>-4</sup> M oxidized glutathione for at least sixteen hours.

18 In some cases (20) and (21) the stearylamine-  
19 containing liposomes were not derivatized with GA but  
20 instead directly reacted with EDAC-activated peptide 309-329  
21 of env gene product. Alternately, (18) and (19), the  
22 activated peptide 309-329 of env gene product was linked to  
23 glutaraldehyde-treated liposomes further derivatized by  
24 reaction with 0.2 M ethylene diamine at pH 8.5 overnight at  
25 20°C followed by floating two times into 0.1 M NaHCO<sub>3</sub>, pH  
26 8.5, reduction with 10uM sodium dithionite for one hour at  
27 20°C and repeated floating into the same buffer. An aliquot  
28 of these liposomes was additionally reacted with  
29

1 EDAC-activated RAT. The liposomes were finally dialyzed  
2 against  $TS-10^{-4}$  M oxidized glutathione.

3 In one preparation (22), stearic acid was used  
4 instead of stearylamine for the preparation of liposomes.  
5 These were dialyzed against 0.01 M NaCl, activated with EDAC  
6 (50 mg/ml for two hours plus additional 25 mg/ml for one  
7 hour) at pH 5.5 and 20°C, floated two times into 0.01 M NaCl  
8 and reacted with the peptide 308-329 of the env gene product  
9 in 1 M  $NaHCO_3$ , pH 8.5, overnight.

10 Polyglutaraldehyde microspheres were prepared as  
11 described by Margel, S., Zisblatt, S. and Rembaum, A.  
12 "Polyglutaraldehyde: A New Reagent For Coupling Proteins To  
13 Microspheres And For Labeling Cell-Surface Receptors. II.  
14 Simplified Labeling Method By Means Of Non-Magnetic And  
15 Magnetic Polyglutaraldehyde Microspheres", Journal of  
16 Immunological Methods, 28, 341-353 (1979), using Polysurf  
17 10-36 B (Bartig Industries Inc., New Canaan, Conn., Margel &  
18 Offarim, (1983)). One mg of the peptide 309-329 of the env  
19 gene product was linked to approximately 50 mg of  
20 microspheres under conditions similar to those described for  
21 glutaraldehyde treated liposomes. Conjugate 25 was prepared  
22 by treating the microspheres with 5 ml of 0.1 M  $\epsilon$ -amino  
23 caproic acid at pH 8.5 overnight. After centrifugation, the  
24 microspheres were suspended in dimethylformamide (2ml) and  
25 reacted with 2 mg EDAC plus 670 ug NHBTA for one hour at  
26 20°C. After centrifugation, the microspheres were  
27 resuspended in 2 ml of 0.1 M  $NaHCO_3$ , pH 8.5, containing 1 mg  
28 of peptide 309-329 of the env gene product.  
29  
30

1 All reagents listed above were of analytical grade  
2 and obtained from Sigma, St. Louis, Missouri, unless  
3 indicated otherwise.

4 Free peptide 309-329 of the env gene product (mol.  
5 weight = 2,664 daltons) containing five cysteine residues  
6 was in a predominantly monomeric form, since it was eluted  
7 after molecular exclusion chromatography in about the same  
8 fractions as insulin A chain. Linking to diaminobutane and  
9 to other diamino-alkanes (data not shown) resulted in  
10 formation of S(135-155) polymers which were immunogenic and  
11 induced both antipeptide and anti-HBs antibodies.

12 Preparations (4), (5) and (7) also induced anti-HBs, while  
13 polymers with diaminooctane or dodecane linkers (6) and (8)  
14 failed to do so (Fig. 8) for reasons not known. Oxidation of  
15 the peptide 309-329 of the env gene product resulted in  
16 polymerization (data not shown). The polymer linked to LPH  
17 (conjugate 9) induced high levels of anti-S(135-155) but no  
18 anti-HBs, unlike S(135-155) linked to KLH or LPH in its  
19 reduced form (Neurath et al., 1982, supra). This finding  
20 again emphasizes the role of peptide conformation in  
21 inducing antibodies to the native protein. Linking of the  
22 oxidized peptide to highly hydrophobic poly-L-valine  
23 resulted in a conjugate (10) of low immunogenicity.  
24 S(135-155) linked to poly-D-lysine administered with  
25 Freund's adjuvant (1) or having covalently linked MDP and  
26 given without adjuvant (3) induced both anti-S(135-155) and  
27 anti-HBs. The latter conjugate administered with Freund's  
28 adjuvant (2) appeared poorly immunogenic. S(135-155) linked  
29 to glutaraldehyde treated liposomes containing stearylamine  
30

1 (conjugate 11) induced levels of anti-HBs comparable to  
2 those elicited by those elicited by conjugates with KLH or  
3 LPH (Neurath et al., 1982, supra). Incorporation of  
4 sphingomyelin and/or lipid A, components reported to enhance  
5 the antigenicity of haptens inserted into liposomal  
6 membranes (Yasuda, T., Dancey, G.F. and Kinsky, S.C.,  
7 "Immunogenicity Of Liposomal Model Membranes In Mice:  
8 Dependence On Phospholipid Composition", Proceedings Of The  
9 National Academy Of Sciences, 74, 1234-1236 (1977)), into  
10 the liposomes (conjugates 13, 15a, 16) failed to enhance  
11 anti-HBs, responses.

12 Conjugates (18 and 19) prepared by linking  
13 S(135-155) to glutaraldehyde-treated liposomes through an  
14 ethylenediamine bridge rather than directly, had the  
15 capacity to induce anti-HBs but a considerable variability  
16 in response between individual rabbits was observed.

17 S(135-155) before or after oxidation and  
18 subsequently linked to stearyl-amine-containing liposomes  
19 (not fixed with glutaraldehyde; preparations 20 and 21) or  
20 to stearic acid-containing liposomes (22) induced low levels  
21 of anti-S-135-155 and no measurable anti-HBs.

22 S(135-155) linked directly to microspheres of  
23 polyglutaraldehyde (preparations 23 and 24) induced a  
24 primary anti-HBs response. However, the level of anti-HBs  
25 decreased in the course of immunization. Anti-HBs was un-  
26 detectable in sera collected two weeks after the third  
27 immunization. S(135-155) linked to these microspheres  
28 through  $\epsilon$ -amino-caproic acid (25) and L-cysteine (26)

29  
30



1 bridges, respectively, either failed (25) or was marginally  
2 efficient (26) in eliciting anti-HBs.

3 S(135-155)-KLH or LPH conjugates elicited a  
4 primary anti-HBs response but the level of anti-HBs failed  
5 to increase in sera of rabbits after additional antigen  
6 doses (Neurath et al., 1982 supra). With the conjugates  
7 described above, generally, a decrease of anti-HBs levels  
8 was observed four or six weeks after primary immunization  
9 (Fig. 9B), but exceptions were observed in a minority of  
10 rabbits (panel 5, Fig. 9A). This declining trend was  
11 uniformly reversed when RAT was inserted into liposomal  
12 membranes together with S(135-155) (for example Fig. 9C and  
13 Fig. 9D).

14 The immunogenicity of haptens inserted into  
15 liposomal membranes depends on the phospholipid composition  
16 of the liposomes and seemed to be inversely related to the  
17 fluidity of these membranes (Yasuda et al., 1977 supra;  
18 Dancey, G.F., Yasuda, T. and Kinsky, S.C., "Effect Of  
19 Liposomal Model Membrane Composition On Immunogenicity", The  
20 Journal Of Immunology, 120, 1109-1113 (1978)).

21 Treatment of stearylamine-containing liposomes  
22 with glutaraldehyde was found to provide reactive groups  
23 suitable for linking of synthetic peptides and at the same  
24 time increases the rigidity of the lipid membranes. Such  
25 liposomes, especially when containing carrier function  
26 enhancing RAT sites (Alkan, S.S., Nitecki, D.E. and Goodman,  
27 J.W., "Antigen Recognition And the Immune Response: The  
28 Capacity of 1-Tryosine-Azobenzenearsonate To Serve As A  
29 Carrier For A Macromolecular Hapten", The Journal Of  
30

1     Immunology, 107, 353-358, (1971), and Alkan, S.S., Williams,  
 2     E.B., Nitecki D.E. and Goodman, J.W.. "Antigen Recognition  
 3     And the Immune Response. Humoral And Cellular Immune  
 4     Responses To Small Mono- And Bifunctional Antigen  
 5     Molecules", The Journal Of Experimental Medicine, 135,  
 6     1228-1246, (1972)), are a promising tool for preparing fully  
 7     synthetic immunogens for eliciting anti-viral antibodies.

TABLE 1

10           List of cross-linkers and carriers used  
 11           for the preparation of S(135-155) conjugates

12		
13	(1)	Poly-D-lysine (mol. weight $3-7 \times 10^4$ )
14	(2)	1 + N-Acetylmuramyl-L-alanyl-D-isoglutamine (MDP)
15	(3)	= 2
16	(4)	1,4-diaminobutane
17	(5)	1,6-diaminohexane
18	(6)	1,8-diaminooctane
19	(7)	1,10-diaminodecane
20	(8)	1,12-diaminododecane
21	(9)	Oxidized S(135-155) linked to LPH
22	(10)	Oxidized S(135-155) linked to poly-L-valine
23	(11)	Liposomes containing stearylamine, and treated 24     with glutaraldehyde
25	(12)	= 11 = L-tyrosine-azobenzene-p-arsonate (RAT)
26	(13)	= 11 + Sphingomyelin (from bovine brain)
27	(14)	= 13 + RAT
28	(15a)	= 11 + Lipid A
29	(15)	= 15a + RAT
30		

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- 1       (16)       = 13 + Lipid A
- 2       (17)       = 16 + RAT
- 3       (18)       = 11 treated with ethylenediamine
- 4       (19)       = 18 + RAT
- 5       (20)       = Liposomes containing stearylamine reacted
- 6                with oxidized S(135-155) (see 9)
- 7       (21)       = 20 except S(135-155) was oxidized after
- attachment to liposomes
- 8       (22)       Stearic acid containing liposomes
- 9       (23)       Polyglutaraldehyde micropheres
- 10       (24)       = 23 + RAT
- 11       (25)       = 23 treated with  $\epsilon$ -aminocaproic acid
- 12       (26)       = 23 treated with L-cysteine

14       Example 8

15               A peptide pre-S (12-32) (subtype adw<sub>2</sub>) was  
16 synthesized according to the procedure described hereinabove  
17 in Example 2. The free peptide, the peptide linked to  
18 glutaraldehyde cross-linked liposomes ( $\pm$ RAT groups)  
19 (according to the procedure described above in Example 7) as  
20 well as the peptide linked to KLH were used to immunize  
21 rabbits. The corresponding antibodies recognized not only  
22 the peptide, but also HBsAg and HBV. In view of the above,  
23 this peptide is believed quite useful for a vaccine against  
24 hepatitis B virus, and as the basis of useful HBV  
25 diagnostics based on either the peptide itself (to detect  
26 anti-HBV response in infected or immunized individuals), or  
27 on peptide antibodies to detect hepatitis B antigens.

1     Example 9

2             A peptide pre-S (117-134) (subtype adw<sub>2</sub>) was  
3     synthesized according to the procedure described hereinabove  
4     in Example 2.

6     Example 10

7             A rabbit was immunized with the peptide pre-S  
8     (117-134) prepared according to Example 9 and linked to a  
9     carrier according to the procedure of Example 7. Such  
10    immunization was conducted according to the procedure  
11    described hereinabove in Example 3 and was found to produce  
12    antibodies in the serum of the rabbit so inoculated.  
13    However, the antibody titers were substantially less than  
14    those observed for the use of pre-S (120-145) and pre-S  
15    (12-32).

17    Example 11

18            The immune response in rabbits to each of two  
19    synthetic peptides corresponding to residues 120-145 and  
20    12-32 of the translational product of the pre-S gene of HBV  
21    DNA (subtype adw<sub>2</sub>) was tested. Peptide pre-S (120-145) was  
22    prepared according to Example 2 and peptide pre-S (12-32)  
23    was prepared according to Example 8. Their sequences are:  
24    MQWNSTAFHQTLQDPRVRGLYLPAGG (pre-S (120-145)) and  
25    MGTNLSVPNPLGFFPDHQLDP (pre-S (12-32)). For immunization,  
26    the peptides were used in free form, employing alum or  
27    Freund's adjuvant, or linked to carriers, i.e., keyhole  
28    lympet hemocyanin (KLH) and cross-linked liposomes,  
29    respectively. The liposomes were prepared as described in  
30

1       Example 7.

2               The best results were obtained with peptides  
3 covalently linked to the surface of liposomes (see Fig.10).  
4 Immunization with KLH conjugates resulted in a high anti-KLH  
5 response (endpoint titers of  $1/5,000,000$  by radio-  
6 immunoassay), apparently causing low booster responses to  
7 the peptides. On the other hand, much lower antibody  
8 responses (approximately  $1/10^3$ ) to RAT groups were detected,  
9 when RAT-containing liposomes were used as carriers.  
10 Antibodies to liposomes (lacking RAT) were undetectable.  
11 This suggests that liposomes are the carrier of choice for  
12 immunization with synthetic peptides.

13  
14       Example 12

15               To establish whether or not antigenic determinants  
16 corresponding to pre-S gene coded sequences are  
17 preferentially present on HBV particles, the reaction of  
18 antisera raised against HBV particles with the two synthetic  
19 peptides analogues of the pre-S protein was tested. The  
20 maximum dilutions of this antiserum at which antibodies  
21 reacting with the synthetic peptides were still detectable  
22 were: approximately  $1/62,500$  ( $1/2 \times 10^6$  with tests utilizing  
23  $^{125}\text{I}$ -labeled protein A instead of labeled second  
24 antibodies), and approximately  $1/2,560$  for peptides  
25 pre-S(120-145) and pre-S(12-32), respectively (see Fig. 11).  
26 The antiserum (adsorbed on HBsAg-Sepharose to remove  
27 antibodies to S-protein) did not react with synthetic  
28 peptide analogues of the S-protein, peptide (309-329) of the  
29 env gene product (S(135-155)), peptide (222-239) of the env  
30 gene product (S(48-65)) and peptide (243-253) of the env

1 gene product (S(69-79)) and was, therefore, specific for  
2 pre-S gene coded sequences. In comparison, the dilution  
3 endpoints of antisera prepared against the homologous  
4 peptides were approximately 1/300,000 and approximately  
5 1/80,000 for anti-pre-S(120-145) (see Fig. 11) and  
6 anti-pre-S(12-32) (data not shown), respectively.

7 The synthetic peptides were recognized also by  
8 antibodies (IgG and IgM) in sera of individuals who had just  
9 recovered from acute hepatitis B, and by rabbit antibodies  
10 against a fusion protein between chloramphenicol  
11 acetyltransferase and a portion of pre-S protein expressed  
12 in E. coli (see Fig. 11).

13 On the other hand, humans vaccinated with  
14 pepsin-treated HBsAg (M.R. Hilleman, E.B. Buynak, W.J.  
15 McAleer, A.A. McLéan, P.J. Provost, A.A. Tytell, in Viral  
16 Hepatitis, 1981 International Symposium, W. Szmuness, H.J.  
17 Alter, J.E. Maynard, Eds. (Franklin Institute Press,  
18 Philadelphia, PA, 1982), pp. 385-397) or with HBsAg produce  
19 in yeast (devoid of pre-S gene coded sequences; W.J.  
20 McAleer, E.B. Buynak, R.F. Maigetter, D.E. Wambler, W.J.  
21 Milbur, M.R. Hilleman, Nature (London), 307, 178 (1984)) did  
22 not develop detectable antibodies recognizing either of the  
23 two synthetic peptides. On the other hand, 7 out of 12  
24 individuals who received a vaccine consisting of intact  
25 HBsAg developed these antibodies.

### 26 Example 13

27  
28 Quantitative aspects of the immunological cross-  
29 reactivity between pre-S gene coded sequences exposed on HB  
30

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1 particles (or on HBsAg) and the synthetic peptide analogues  
2 were tested. The peptides were conjugated to  
3  $\beta$ -galactosidase, and the inhibitory effect of free peptides,  
4 HBV and HBsAg, respectively, on the formation of immune  
5 complexes containing the enzyme-conjugated peptide was  
6 studied. Results shown in Fig. 12 indicate that HBV. at  
7 sufficient concentrations, inhibited completely the reaction  
8 between anti-pre-S(120-145) and pre-S(120-145)-  
9  $\beta$ -galactosidase. HBsAg had  $< 1/5$  of the inhibitory activity  
10 corresponding to HBV. The inhibitory activity of  
11 pepsin-treated HBsAg was  $< 1/1,000$  of the activity  
12 corresponding to intact HBsAg. These results indicate the  
13 absence in the anti-pre-S(120-145) serum of a subpopulation  
14 of antibodies which recognize the synthetic peptide but not  
15 the native protein. Such antibody subpopulations are  
16 observed in many other antisera raised against synthetic  
17 peptide analogues of viral proteins. The concentration of  
18 free peptide sufficient for approximately 50% inhibition of  
19 the reaction of pre-S(120-145)- $\beta$ -galactosidase with  
20 anti-pre-S(120-145) is approximately 1/100 of that for HBV  
21 on a weight basis (see Fig. 11). However, since the  
22 molecular weight of pre-S(120-145) is approximately 3 kD and  
23 the molecular weight of HBV protein components reacting with  
24 anti-pre-S(120-145) (representing a minor ( $< 20\%$ ) portion of  
25 the total HBV mass) is between approximately 33 and  
26 approximately 67 kD, the molar concentrations of HBV and  
27 pre-S(120-145) required for this degree of inhibition are  
28 approximately the same. This indicates that the antigenic  
29 determinants on the peptide analogue and on the  
30

1 corresponding segment of the HBV envelope protein(s) are  
2 structurally closely related.

3  
4 Example 14

5 A peptide pre-S (94-117) (subtype adw<sub>2</sub>) was  
6 synthesized according to the procedure described hereinabove  
7 in Example 2.

8  
9 Example 15

10 A rabbit was immunized with the peptide pre-S  
11 (94-117) prepared according to Example 14 and linked to a  
12 carrier according to the procedure of Example 7. Such  
13 immunization was conducted according to the procedure  
14 described hereinabove for Example 3 and was found to produce  
15 antibodies in the serum of the rabbit so inoculated.  
16 However, the antibody titers were substantially less than  
17 those observed for the use of pre-S (120-145) and pre-S  
18 (12-32).

19  
20  
21 Example 16

22 A peptide pre-S (153-171) (subtype adw<sub>2</sub>) was  
23 synthesized according to the procedure described hereinabove  
24 in Example 2.

25  
26 Example 17

27 A rabbit was immunized with the peptide pre-S  
28 (153-171) prepared according to Example 16 and linked to a  
29 carrier according to the procedure of Example 7. Such  
30 immunization was conducted according to the procedure



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1 described hereinabove for Example 3 and was found to produce  
2 antibodies in the serum of the rabbit so inoculated.  
3 However, the antibody titers were substantially less than  
4 those observed for the use of pre-S (120-145) and pre-S  
5 (12-32).  
6

7 Example 18

8 A peptide pre-S (1-21) (subtype adw<sub>2</sub>) was  
9 synthesized according to the procedure described hereinabove  
10 in Example 2.  
11

12 Example 19

13 A rabbit was immunized with the peptide pre-S  
14 (1-21) prepared according to Example 18 and linked to a  
15 carrier according to the procedure of Example 7. Such  
16 immunization was conducted according to the procedure  
17 described hereinabove for Example 3 and was found to produce  
18 antibodies in the serum of the rabbit so inoculated.  
19 However, the antibody titers were substantially less than  
20 those observed for the use of pre-S (120-145) and pre-S  
21 (12-32).  
22

23 Example 20

24 A peptide pre-S (32-53) (subtype adw<sub>2</sub>) was  
25 synthesized according to the procedure described hereinabove  
26 in Example 2.  
27  
28  
29  
30

Example 21

A rabbit was immunized with the peptide pre-S (32-53) prepared according to Example 20 and linked to a carrier according to the procedure of Example 7. Such immunization was conducted according to the procedure described hereinabove for Example 3 and was found to produce antibodies in the serum of the rabbit so inoculated. However, the antibody titers were substantially less than those observed for the use of pre-S (120-145) and pre-S (12-32).

Example 22

A peptide pre-S (57-73) (subtype adw<sub>2</sub>) was synthesized according to the procedure described hereinabove in Example 2.

Example 23

A rabbit was immunized with the peptide pre-S (57-73) prepared according to Example 22 and linked to a carrier according to the procedure of Example 7. Such immunization was conducted according to the procedure described hereinabove for Example 3 and was found to produce antibodies in the serum of the rabbit so inoculated. However, the antibody titers were substantially less than those observed for the use of pre-S (120-145) and pre-S (12-32).

1     Example 24

2             Detection of anti-pre-S protein antibodies in  
3     human sera using synthetic peptides.

4             As discussed above, antibodies recognizing  
5     synthetic peptide analogues of the pre-S protein were  
6     detected in sera of humans during recovery from hepatitis B  
7     (Fig. 11). The time course of development of antibodies  
8     recognizing pre-S(120-145) in a selected patient is shown in  
9     Fig. 13.

10            Anti-pre-S protein antibodies are detected in  
11     human sera early during acute hepatitis type B. IgM  
12     antibodies recognizing the peptides were detected during  
13     HBsAg antigenemia before antibodies to the S-protein  
14     (anti-HBs) or to hepatitis B core antigen (anti-HBc) were  
15     detectable. After development of the latter two antibodies,  
16     the level of antibodies with anti-pre-S specificity  
17     declined. Variations of this pattern of anti-pre-S  
18     development among patients with hepatitis B were observed.  
19     In some cases, antibodies recognizing the synthetic peptides  
20     were present even before HBsAg was detected in plasma, or  
21     when HBsAg never appeared in blood and the only marker for  
22     hepatitis B was anti-HBc and later anti-HBs.

23            Antibodies to pre-S(120-145) were measured by RIA.  
24     Similar results were obtained by assaying antibodies to  
25     pre-S(12-32). HBsAg, anti-HBs and antibodies to hepatitis B  
26     core antigen (anti-HBc) were assayed using commercial test  
27     kits (Abbot Laboratories, North Chicago, Illinois). The  
28     broken line at the end of bars corresponding to the  
29     different markers of HBV infection indicates positivity at  
30

1 the termination of surveillance. Antibody titers represent  
2 the highest dilution of serum at which radioactivity counts  
3 corresponding to the specimens divided by counts  
4 corresponding to equally diluted control serum were  $\geq 2.1$ .

5 Humans vaccinated with pepsin-treated HBsAg  
6 (Hilleman, M.R., Buynak, E.B., McAleer, W.J., McLean, A.A.,  
7 Provost, P.J. & Tytell, A.A. in Viral Hepatitis, 1981  
8 International Symposium (eds. Szmuness, W., Alter, H.J. &  
9 Maynard, J.E.) 385-397 (Franklin Institute Press,  
10 Philadelphia, PA, 1982)), (pepsin treatment removes all  
11 anti-pre-S(120-145) reactive material), or with HBsAg  
12 produced in yeast (devoid of pre-S gene coded sequences  
13 (McAleer, W.J. Buynak, E.B. Maigetter, R.Z., Wambler, D.E.,  
14 Miller, W.J., Hillemann, M.R. Nature, (London), 307, 178-180  
15 (1984); did not develop detectable antibodies recognizing  
16 either of the two synthetic peptides. On the other hand, 7  
17 out of 12 individuals who received a vaccine consisting of  
18 intact HBsAg (McAuliffe, V.J., Purcell, R.H., Gerin, J.L. &  
19 Tyeryar, F.J. in Viral Hepatitis (eds Szmuness, W., Alter,  
20 H.J. & Maynard, J.E.) 425-435, Franklin Institute Press,  
21 Philadelphia, PA) developed these antibodies. These 7  
22 individuals also had the highest antibody response to the  
23 S-protein, as measured by the AUSAB test (Abbott),  
24 suggesting that a lack of detectable response to the pre-S  
25 protein was due to the sensitivity limits of the test. In  
26 this respect, it is of importance that the hepatitis B  
27 vaccine heretofore used, the production of which involves  
28 pepsin treatment of HBsAg, although highly efficient in  
29 apparently healthy individuals, has had low immunogenicity  
30

1 and no protective effect in hemodialysis patients (Stevens,  
2 C.E., Alter, H.J., Taylor, P.E., Zang, E.A., Harley, E.J. &  
3 Szmuness, W., N. Engl. J. Med., 311, 496-501 (1984)). Other  
4 vaccines produced without pepsin treatment do not seem to  
5 have this defect (Desmyter, J. in Viral Hepatitis and Liver  
6 Disease (eds Vyas, G.N., Dienstag, J.L. & Hoofnagle, J.), in  
7 press Grune and Stratton, Orlando, Fl. 1984).

8  
9 Example 25

10 RIA Tests of Preparations Containing HBV-specific  
11 proteins

12 Antibodies to the S-protein were removed from  
13 rabbit anti-serum against HBV particles by affinity  
14 chromatography (Neurath, A.R., Trepo, C., Chen, M., Prince,  
15 A.M., J. Gen. Virol., 30, 277-285 (1976) - See Fig. 14. The  
16 tested antigens were: HBV particles and tubular forms (●,  
17 Δ); approximately 20 nm spherical particles of HBsAg isolated  
18 from plasma (○, Δ); and the latter particles treated with  
19 pepsin (1 mg/ml HBsAg, 50ug/ml pepsin in 0.1 M glycine-HCl,  
20 pH 2.2, 2 hours at 37°C) (□). The RIA tests were performed  
21 as described in Neurath; A.R., Kent, S.B.H., Strick, N.,  
22 Science, 224, 392-395 (1984). The concentration of HBsAg  
23 S-protein was adjusted to the same level in all preparations  
24 tested as based on RIA tests (AUSRIA, Abbot Laboratories).  
25 HBV particles (contaminated with tubular forms of HBsAg)  
26 were concentrated from serum approximately 100x by  
27 centrifugation for 4 hours at 25,000 rpm in a Spinco 35  
28 rotor. The concentrate (2 ml) was layered over a  
29 discontinuous gradient consisting of 11 ml of each 20, 10  
30

1 and 5% sucrose (w/w) in 0.14 M NaCl-0.01 M Tris-0.02% NaN<sub>3</sub>,  
2 pH 7.2 (TS) and centrifuged for 16 hours at 25,000 rpm in a  
3 Spinco rotor SW 27. The final pellet was resuspended in TS.

4 HBV particles were recognized much more  
5 efficiently than purified approximately 22 nm spherical  
6 particles in RIA tests based on polystyrene beads coated  
7 with either anti-pre-S(120-145) or with rabbit antibodies to  
8 HBV particles. Treatment of HBsAg with pepsin, a step used  
9 in preparing some current hepatitis B vaccines, resulted in  
10 an approximately 10<sup>3</sup>-fold decrease in reactivity with  
11 anti-pre-S(120-145). HBsAg from vaccines derived either from  
12 infected plasma (Hilleman, M.R., et al, 1982) supra, or  
13 produced in yeast McAleer et al (1984), supra, had  $\leq$   
14 1/5,000 of the reactivity of intact HBsAg in these tests.

15 In reverse tests, beads coated with HBsAg, with  
16 HBV particles, with pepsin-treated HBsAg, or with HBsAg  
17 corresponding to the vaccines mentioned above were utilized.  
18 IgG antibodies (from different rabbit antisera to pre-S  
19 sequences) reacting with the beads were assayed based on the  
20 subsequent attachment of labeled anti-rabbit IgG. Positive  
21 results using anti-pre-S(120-145) were obtained only with  
22 beads coated with intact HBsAg or with HBV particles.  
23 Anti-pre-S(12-32) reacted exclusively with HBV-coated beads.

#### 24 Example 26

#### 25 Involvement of pre-S Gene Coded HBV Domains In 26 Attachment to Cell Receptors

27 It has been suggested that the 55 C-terminal amino  
28 acids of the pre-S protein mediate the attachment of HBsAg  
29 to human albumin polymerized by glutaraldehyde (pHSA) and  
30

1 that this attachment plays an essential role in the in vivo  
2 adsorption of HBV to hepatocytes (Machida, A. et al,  
3 Gastroenterology, 86, 910-918, (1984); Machida, A. et al,  
4 Gastroenterology, 85, 268-274, (1983). However, there is no  
5 compelling evidence to support the role of the pHSA-HBV  
6 interaction in infection of liver cells by HBV. In  
7 addition, both HBsAg containing or lacking these 55 amino  
8 acid residues react with pHSA (Fig. 15), albeit the reaction  
9 is enhanced by the presence of the pre-S gene coded  
10 sequences. The RIA tests involved in Fig. 15 were conducted  
11 as described in Neurath, A.R., Strick, N. Intervirology, 11,  
12 128-132 (1979).

13 To explore directly the reaction of HBsAg with  
14 liver cells, an assay system based on the attachment of  
15 liver cells to insolubilized HBsAg was developed.

16 HBsAg (HBV) was attached to  
17 N-N'-p-phenylenedimaleimide-derivatized sulfhydryl cellulose  
18 under conditions described for linking of pre-S(120-145), as  
19 described above. About 4 mg of HBsAg was linked to 1 g of  
20 the cellulose derivative. A control cellulose derivative  
21 was prepared by linking bovine serum albumin to the  
22 activated matrix. Forty mg of the cellulose derivative  
23 suspended in TS containing 10 mg/ml of bovine serum albumin  
24 (TS-BSA) were mixed with approximately  $2 \times 10^6$  washed Hep G2  
25 human hepatoma cells (see Aden, D.P., Fogel, A., Plotkin,  
26 S., Damjanov, J., Knowles, B.B., Nature (London), 282,  
27 615-617 (1979) suspended in TS-BSA and incubated for 30 min  
28 at 37°C, followed by 1 hour at 4°C. HeLa cells and Clone 9  
29 normal rat liver cells (American Type Culture Collection)  
30

1 were used as controls. The cell-cellulose mixtures were  
2 layered on top of 1 ml of 33% (w/w) Hypaque and centrifuged  
3 for 2 minutes at 3,000 rpm. The cellulose derivative with  
4 attached cells pelleted under these conditions. Unattached  
5 cells recovered from the Hypaque-TS-BSA interphase were  
6 diluted 5-fold in TS-BSA and pelleted by centrifugation.  
7 The relative proportion of adsorbed and unadsorbed cells was  
8 determined by measurement of lactate dehydrogenase (LDH)  
9 activity in appropriate aliquots of cell lysates obtained  
10 after exposure to the detergent Triton X-100 (5 mg/ml in  
11 H<sub>2</sub>O). LDH activity was determined using diagnostic kit No.  
12 500 (Sigma).

13 Approximately 80 to 95% of human hepatoma Hep G2  
14 cells (Aden, D.P. supra) attached to immobilized HBsAg in  
15 this assay. The attachment of control cells (HeLa, rat  
16 hepatocytes) was in the range of 10 to 20%. About 10% of  
17 Hep G2 cells attached to control cellulose. In the presence  
18 of anti-pre-S(120-145) and anti-pre-S(12-32) IgG (15 mg/ml),  
19 the adsorption of Hep G2 cells to HBsAg-cellulose decreased  
20 to 60 and 30%, respectively. A mixture of both antibodies  
21 (7.5 mg/ml of IgG each) caused a decrease of cell adsorption  
22 to 20%, indistinguishable from background levels.

23 Normal rabbit IgG, as well as antibodies to the  
24 S-protein (elicited by immunization with pepsin-treated  
25 HBsAg), failed to diminish the cell attachment, despite high  
26 levels of anti-HBs present in this serum (positive at a 10<sup>-6</sup>  
27 dilution in the AUSAB test).

28  
29 It will be appreciated that the instant  
30 specification and claims are set forth by way of



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1 illustration and not limitation and that various  
2 modifications and changes may be made without departing from  
3 the spirit and scope of the present invention.  
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1     WHAT IS CLAIMED IS:  
2

3             1.    A hepatitis B peptide immunogen comprising  
4                    a peptide containing an amino acid chain  
5             corresponding to at least six consecutive amino acids within  
6             the pre-S gene coded region of the envelope of HBV, said  
7             peptide immunogen free of an amino acid sequence  
8             corresponding to the naturally occurring envelope proteins  
9             of hepatitis B virus.

10            2.    A hepatitis B peptide immunogen according to  
11            claim 1, wherein said chain of amino acids is between  
12            sequence position pre-S 120 and pre-S 174.

13            3.    A hepatitis B peptide immunogen according to  
14            claim 2, wherein said chain of amino acids includes  
15            N-terminal methionine at sequence position pre-S 120.

16            4.    A hepatitis B peptide immunogen according to  
17            claim 1, wherein said chain of amino acids is between  
18            sequence position pre-S 1 and pre-S 120.

19            5.    A hepatitis B peptide immunogen according to  
20            claim 1, wherein said peptide contains a chain of at least  
21            10 amino acids.

22            6.    A hepatitis B peptide immunogen according to  
23            claim 1, wherein said peptide contains a chain of at least  
24            15 amino acids.

25            7.    A hepatitis B peptide immunogen according to  
26            claim 1, wherein said peptide contains a chain of at least  
27            20 amino acids.  
28  
29  
30

1           8. A hepatitis B peptide immunogen according to  
2 claim 1, wherein said peptide contains a chain of at least  
3 26 amino acids.

4           9. A hepatitis B peptide immunogen according to  
5 claim 8, wherein said chain is between and including  
6 sequence positions pre-S 120 and pre-S 174.

7           10. A hepatitis B peptide immunogen according to  
8 claim 9, wherein said chain includes N-terminal methionine  
9 at sequence position pre-S 120.

10           11. A hepatitis B peptide immunogen according to  
11 claim 1, wherein said chain is between and including  
12 sequence position pre-S 15 and pre-S 120.

13           12. A hepatitis B peptide immunogen according to  
14 claim 1, wherein said chain is between and including  
15 sequence position pre-S 15 and pre-S 55.

16           13. A hepatitis B peptide immunogen according to  
17 claim 1, wherein said chain is between and including  
18 sequence position pre-S 90 and pre-S 120.

19           14. A hepatitis B peptide immunogen according to  
20 claim 1, wherein said chain is between and including  
21 sequence position pre-S 10 and pre-S 40.

22           15. A hepatitis B peptide immunogen according to  
23 claim 1, wherein said chain corresponds to amino acids in  
24 the ayw subtype of the pre-S region.

25           16. A hepatitis B peptide immunogen according to  
26 claim 1, wherein said chain corresponds to amino acids in  
27 the adyw subtype of the pre-S region.  
28  
29  
30

1           17. A hepatitis B peptide immunogen according to  
2 claim 1, wherein said chain corresponds to amino acids in  
3 the adw2 subtype of the pre-S region.

4           18. A hepatitis B peptide immunogen according to  
5 claim 1, wherein said chain corresponds to amino acid in the  
6 adw subtype of the pre-S region.

7           19. A hepatitis B peptide immunogen according to  
8 claim 1, wherein said chain corresponds to amino acids in  
9 the adr subtype of the pre-S region.

10          20. A hepatitis B peptide immunogen according to  
11 claim 1, wherein said peptide immunogen is free of any serum  
12 proteins.

13          21. A hepatitis B peptide immunogen according to  
14 claim 1, wherein said chain is MQWNSTAFHQTLQDPRVRGLYLPAGG.

15          22. A hepatitis B peptide immunogen according to  
16 claim 1, wherein said chain is MGTNLSVPNPLGFFPDHQLDP.

17          23. A hepatitis B peptide immunogen according to  
18 claim 1, wherein said chain is PAFGANSNNPDWFNPKDDWP.

19          24. A hepatitis B peptide immunogen according to  
20 claim 1, wherein said chain is PQAMQWNSTAFHQTLQDP.

21          25. A hepatitis B peptide immunogen according to  
22 claim 1, wherein said chain is PASTNRQSGRQPTISPPLRDSHP.

23          26. A hepatitis B peptide immunogen according to  
24 claim 1, wherein said chain is PAPNIASHISSISARTGDP.

25          27. A hepatitis B peptide immunogen according to  
26 claim 1, wherein said chain is MGGWSSKPRKMGMTNLSVNP.

27          28. A hepatitis B peptide immunogen according to  
28 claim 1, wherein said chain is PAFGANSNNPDWFNPKDDWP.  
29  
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1           29. A hepatitis B peptide immunogen according to  
2 claim 1, wherein said chain is QVGVGAFGPRLTPPHGG.

3           30. A hepatitis B peptide immunogen according to  
4 claim 1, wherein said chain is MGGWSSKPRKG.

5           31. A hepatitis B peptide immunogen according to  
6 claim 1, wherein said chain is MGGWSSKPRQG.

7           32. A hepatitis B peptide immunogen according to  
8 claim 1, wherein said peptide immunogen is free of an amino  
9 acid sequence corresponding to the entire S gene coded  
10 region of the env gene product of hepatitis B virus.

11           33. A hepatitis B peptide immunogen according to  
12 claim 1, wherein said peptide has no more than 100 amino  
13 acids.

14           34. A hepatitis B peptide immunogen according to  
15 claim 1, wherein said peptide has no more than 40 amino  
16 acids.

17           35. A hepatitis B peptide immunogen according to  
18 claim 1, wherein said peptide has no more than 30 amino  
19 acids.

20           36. A hepatitis B peptide immunogen according to  
21 claim 1, wherein said peptide is capable of forming  
22 neutralizing antibodies to hepatitis B virus in a humans.

23           37. A hepatitis B peptide immunogen according to  
24 claim 1, wherein said peptide is linked to a carrier.

25           38. A hepatitis B peptide immunogen according to  
26 claim 37, wherein said peptide is covalently linked to a  
27 carrier.  
28  
29  
30

1                   39. A hepatitis B peptide immunogen according to  
2 claim 38, wherein said peptide is covalently linked to a  
3 lipid vesicle carrier.

4                   40. A hepatitis B peptide immunogen according to  
5 claim 39, wherein said lipid vesicle is stabilized by  
6 cross-linking.

7                   41. A hepatitis B peptide immunogen according to  
8 claim 1, wherein said chain is pre-S(120-145) ..

9                   42. A hepatitis B peptide immunogen according to  
10 claim 1, wherein said chain is pre-S(12-32).

11                   43. A hepatitis B peptide immunogen according to  
12 claim 1, wherein said chain is pre-S(117-134).

13                   44. A hepatitis B peptide immunogen according to  
14 claim 1, wherein said chain is pre-S(94-117).

15                   45. A hepatitis B peptide immunogen according to  
16 claim 1, wherein said chain is pre-S(153-171).

17                   46. A hepatitis B peptide immunogen according to  
18 claim 1, wherein said chain is pre-S(1-21).

19                   47. A hepatitis B peptide immunogen according to  
20 claim 1, wherein said chain is pre-S(57-73).

21                   48. A carrier for a peptide comprising a lipid  
22 vesicle stabilized by cross-linking and having covalently  
23 bonded active sites on the outer surface thereof to bind the  
24 peptide to the outer surface of the carrier.

25                   49. A carrier according to claim 48, wherein said  
26 active sites are selected from the group consisting of  
27 -COOH, -CHO, -NH<sub>2</sub> and -SH.  
28

29                   50. A carrier according to claim 49, wherein said  
30 lipid vesicle contains an amino moiety selected from the

1 group consisting of aminoalkane, diaminoalkane, aminoalkene  
2 and diaminoalkene having 10 to 18 carbon atoms and said  
3 lipid vesicle is stabilized by contacting said lipid vesicle  
4 with a polyaldehyde.

5 51. A carrier according to claim 50, wherein said  
6 polyaldehyde is a bifunctional aldehyde.

7 52. A carrier according to claim 51, wherein said  
8 bisaldehyde is glutaraldehyde.

9 53. A carrier according to claim 50, wherein said  
10 amino moiety is stearylamine.

11 54. A carrier according to claim 52, wherein said  
12 amino moiety is stearylamine.

13 55. A carrier according to claim 48, wherein said  
14 lipid vesicle contains fatty acids having 12 to 18 carbon  
15 atoms and said lipid vesicle is stabilized with a  
16 carbodiimide.

17 56. A carrier according to claim 55, wherein said  
18 fatty acid is stearic acid and said carbodiimide is  
19 N-ethyl-N' (dimethyl-aminopropyl)-carbodiimide.

20 57. A carrier according to claim 48, wherein said  
21 lipid vesicle contains fatty acid aldehyde.

22 58. A peptide linked to a carrier comprising a  
23 peptide having -SH groups and a carrier comprising a liquid  
24 vesicle containing an amino moiety selected from the group  
25 consisting of aminoalkane, diaminoalkane, aminoalkene,  
26 diaminoalkene having 10 to 18 carbon atoms activated by a  
27 polyaldehyde and further activated by cysteine.

28 59. A peptide linked to a carrier according to  
29 claim 58, wherein said -SH groups are supplied by cysteine.  
30

1                   60. A peptide linked to a carrier comprising a  
2 peptide having -SH groups and a carrier comprising a lipid  
3 vesicle containing fatty acid mercaptan.

4                   61. A peptide linked to a carrier according to  
5 claim 60, wherein said fatty acid mercaptan is  
6 octadecanethiol.

7                   62. A peptide linked to a carrier according to  
8 claim 60, wherein said fatty acid mercaptan contains lipid  
9 vesicle activated with a dimaleimide.

10                  63. A peptide linked to a carrier according to  
11 claim 52, wherein said dimaleimide is N-N'-phenylanedi-  
12 maleimide.

13                  64. A peptide linked to a carrier comprising a  
14 peptide activated by a carbodiimide and a carrier comprising  
15 a lipid vesicle containing an amino moiety selected from the  
16 group consisting of aminoalkane, diaminoalkane, aminoalkene,  
17 diaminoalkene having 10 to 18 carbon atoms.

18                  65. A peptide linked to a carrier according to  
19 claim 64, wherein said amino moiety is stearylamine.

20                  66. A peptide linked to a carrier according to  
21 claim 64, wherein said carbodiimide is  
22 N-ethyl-N' (dimethylaminopropyl)-carbodiimide.

23                  67. A peptide linked to a carrier comprising a  
24 peptide activated by a carbodiimide and a carrier comprising  
25 a lipid vesicle stabilized by a polyaldehyde and further  
26 derivatized by reaction with a water-soluble diaminoalkane.

27                  68. A peptide linked to a carrier according to  
28 claim 67, wherein said carbodiimide is N-ethyl-N' (di-  
29

30



1 methylaminopropyl)-carbodiimide, said polyaldehyde is  
2 glutaraldehyde and said diaminoalkane is ethylenediamine.

3 69. A method of forming a carrier comprising  
4 contacting a lipid vesicle containing an amino moiety  
5 selected from the group consisting of aminoalkane,  
6 diaminoalkane, aminoalkene and diaminoalkene having 10 to 18  
7 carbon atoms with a polyaldehyde.

8 70. A method according to claim 69, wherein said  
9 amino moiety is stearylamine.

10 71. A method according to claim 69, wherein said  
11 polyaldehyde is glutaraldehyde.

12 72. A method of forming a carrier comprising  
13 contacting a lipid vesicle containing fatty acid having 12  
14 to 18 carbon atoms with a carbodiimide.

15 73. A method of forming a carrier according to  
16 claim 72, wherein said fatty acid is stearic acid and said  
17 carbodiimide is N-ethyl-N'(dimethylaminopropyl)-  
18 carbodiimide.

19 74. A method of forming a carrier comprising  
20 contacting a lipid vesicle with a fatty acid aldehyde.

21 75. A method of linking a peptide to a carrier  
22 comprising contacting a peptide having -SH groups with a  
23 carrier comprising a lipid vesicle containing an amino  
24 moiety selected from the group consisting of aminoalkane,  
25 diaminoalkane, aminoalkene and diaminoalkene having 10 to 18  
26 carbon atoms and contacting said lipid vesicle with a  
27 polyaldehyde and cysteine.

28 76. A method of linking a peptide to a carrier  
29 comprising contacting a peptide having -SH groups with a  
30

1 carrier comprising a lipid vesicle having fatty acid  
2 mercaptan.

3 77. A method of linking a peptide to a carrier  
4 according to claim 76, wherein said fatty acid mercaptan is  
5 octadecanediol.

6 78. A method of linking a peptide to a carrier  
7 according to claim 77, wherein said fatty acid mercaptan  
8 containing lipid vesicle is contacted with a dimaleimide.

9 79. A method according to claim 78, wherein said  
10 dimaleimide is N-N'-phenylanedimaleimide.

11 80. A method of linking a peptide to a carrier  
12 comprising contacting a peptide, said peptide contacted with  
13 a carbodiimide, with a carrier, said carrier comprising an  
14 lipid vesicle containing an amino moiety selected from the  
15 group consisting of aminoalkane, diaminoalkane, aminoalkene  
16 and diaminoalkene having 10 to 18 carbon atoms.

17 81. A method according to claim 80, wherein said  
18 amino moiety is stearylamine and said carbodiimide is  
19 N-ethyl-N' (dimethylaminopropyl)-carbodiimide.

20 82. A method of linking a peptide to a carrier  
21 comprising contacting a peptide activated by a carbodiimide  
22 and a carrier comprising a lipid vesicle stabilized by a  
23 polyaldehyde and further reacted with a water-soluble  
24 diaminoalkane.

25 83. A method of linking a peptide to a carrier  
26 according to claim 82, wherein said polyaldehyde is  
27 glutaraldehyde and said diaminoalkane is ethylenediamine.

28 84. A peptide comprising an amino acid chain  
29 corresponding to at least six consecutive amino acids within  
30

1 the pre-S gene coded region of the envelope of HBV, said  
2 peptide free of an amino acid sequence corresponding to the  
3 naturally occurring envelope proteins of hepatitis B virus.

4 85. A peptide according to claim 84, wherein  
5 said chain of amino acids is between sequence position pre-S  
6 120 and pre-S 174.

7 86. A peptide according to claim 85, wherein  
8 said chain of amino acids includes N-terminal methionine at  
9 sequence position pre-S 120.

10 87. A peptide according to claim 84, wherein  
11 said chain of amino acids is between sequence position pre-S  
12 1 and pre-S 120.

13 88. A peptide according to claim 84, wherein  
14 said peptide contains a chain of at least 10 amino acids.

15 89. A peptide according to claim 84, wherein  
16 said peptide contains a chain of at least 15 amino acids.

17 90. A peptide according to claim 84, wherein  
18 said peptide contains a chain of at least 20 amino acids.

19 91. A peptide according to claim 84, wherein  
20 said peptide contains a chain of at least 26 amino acids.

21 92. A peptide according to claim 91, wherein  
22 said chain is between and including sequence positions pre-S  
23 120 and pre-S 174.

24 93. A peptide according to claim 92, wherein  
25 said chain includes N-terminal methionine at sequence  
26 position pre-S 120.

27 94. A peptide according to claim 84, wherein  
28 said chain is between and including sequence position pre-S  
29 15 and pre-S 120.  
30

- 1                   95. A peptide according to claim 84, wherein  
2 said chain is between and including sequence position pre-S  
3 15 and pre-S 55.
- 4                   96. A peptide according to claim 84, wherein  
5 said chain is between and including sequence position pre-S  
6 90 and pre-S 120.
- 7                   97. A peptide according to claim 84, wherein  
8 said chain is between and including sequence position pre-S  
9 10 and pre-S 40.
- 10                  98. A peptide according to claim 84, wherein  
11 said chain corresponds to amino acids in the ayw subtype of  
12 the pre-S region.
- 13                  99. A peptide according to claim 84, wherein  
14 said chain corresponds to amino acids in the adyw subtype of  
15 the pre-S region.
- 16                  100. A peptide according to claim 84, wherein  
17 said chain corresponds to amino acids in the adw2 subtype of  
18 the pre-S region.
- 19                  101. A peptide according to claim 84, wherein  
20 said claim corresponds to amino acids in the adw subtype of  
21 the pre-S region.
- 22                  102. A peptide according to claim 84, wherein  
23 said chain corresponds to amino acids in the adr subtype of  
24 the pre-S region.
- 25                  103. A peptide according to claim 84, wherein  
26 said peptide is MQWNSTAFHQTLQDPRVRGLYLPAGG.
- 27                  104. A peptide according to claim 84, wherein  
28 said peptide is MGTNLSVPNPLGFFPDHQLDP.
- 29  
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1           105. A peptide according to claim 84, wherein  
2 said peptide is PAFGANSNPWFNPNVKDDWP.

3           106. A peptide according to claim 84, wherein  
4 said peptide is PQAMQWNSTAFHQTLQDP.

5           107. A peptide according to claim 84, wherein  
6 said peptide is PASTNRQSGRQPTPISPPLRDSHP.

7           108. A peptide according to claim 84, wherein  
8 said peptide is PAPNIASHISSISARTGDP.

9           109. A peptide according to claim 84, wherein  
10 said peptide is MGGWSSKPRKGMGTNLSVNP.

11           110. A peptide according to claim 84, wherein  
12 said peptide is PAFGANSNNPDWDFNPNVKDDWP.

13           111. A peptide according to claim 84, wherein  
14 said peptide is QVGVGAFGPRLTPPHGG.

15           112. A peptide according to claim 84, wherein  
16 said peptide is MGGWSSKPRKG.

17           113. A peptide according to claim 84, wherein  
18 said peptide is MGGWSSKPRKG.

19           114. A peptide according to claim 84, wherein  
20 said peptide is free of an amino acid sequence corresponding  
21 to the entire S gene coded region of the surface antigen of  
22 hepatitis B virus.

23           115. A peptide according to claim 84, wherein  
24 said peptide has no more than 100 amino acids.

25           116. A peptide according to claim 84, wherein  
26 said peptide has no more than 40 amino acids.

27           117. A peptide according to claim 84, wherein  
28 said peptide has no more than 30 amino acids.  
29  
30

- 1                   118. A peptide according to claim 84, wherein  
2                   said chain is pre-S(120-145).  
3                   119. A peptide according to claim 84, wherein  
4                   said chain is pre-S(12-32).  
5                   120. A peptide according to claim 84, wherein  
6                   said chain is pre-S(117-134).  
7                   121. A peptide according to claim 84, wherein said  
8                   chain is pre-S(94-117).  
9                   122. A peptide according to claim 84, wherein  
10                  said chain is pre-S(153-171).  
11                  123. A peptide according to claim 84, wherein  
12                  said chain is pre-S(1-21).  
13                  124. A peptide according to claim 84, wherein  
14                  said chain is pre-S(57-73).  
15                  125. A process for the detection of antigens  
16                  coded for the pre-S gene in sera of HBV infected animals  
17                  comprising:  
18                   (a) coating a solid substrate with  
19                   antibodies to a peptide having an amino acid chain  
20                   corresponding to at least six consecutive amino acids within  
21                   the pre-S gene coded region of the envelope of HBV, said  
22                   peptide free of an amino acid sequence corresponding to the  
23                   naturally occurring proteins of HBV;  
24                   (b) washing the coated substrate;  
25                   (c) contacting the washed coated substrate  
26                   with a protein-containing solution;  
27                   (d) washing the substrate from step c;  
28                   (e) incubating the substrate from step d  
29                   with a sample suspected to contain HBV or HBsAg;  
30

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1 (f) washing the substrate from step e;  
2 (g) adding radiolabeled antibody, said  
3 antibody being an antibody to the peptide or HBsAg, to the  
4 substrate from step f;  
5 (h) incubating the substrate from step g;  
6 (i) washing the substrate from step h; and  
7 (j) subjecting the substrate of step i to  
8 counting in a gamma counter.

9 126. A process for the detection of antigen coded  
10 for by the pre-S gene in sera of HBV infected animals  
11 according to claim 125, wherein said substrate is  
12 polystyrene beads.

13 127. A process for the detection of antigen coded  
14 for by the pre-S gene in sera of HBV infected animals  
15 according to claim 125, wherein said protein-containing  
16 solution contains bovine serum albumin or gelatin.

17 128. A process for the detection of antigens coded  
18 for the pre-S gene in sera of HBV infected animals  
19 comprising:  
20

21 (a) coating a solid substrate with  
22 antibodies to a peptide having an amino acid chain  
23 corresponding to at least six consecutive amino acids within  
24 the pre-S gene coded region of the envelope of HBV, said  
25 peptide free of an amino acid sequence corresponding to the  
26 naturally occurring proteins of HBV;

27 (b) washing the coated substrate;  
28 (c) contacting the washed coated substrate  
29 with a protein-containing solution;

30 (d) washing the substrate from step c;

- 1 (e) incubating the substrate from step d
- 2 with a sample suspected to contain HBV or HBsAg;
- 3 (f) washing the substrate from step e;
- 4 (g) adding enzyme labeled antibody, said
- 5 antibody being an antibody to the peptide or HBsAg, to the
- 6 substrate from step f;
- 7 (h) incubating the substrate from step g;
- 8 (i) washing the substrate from step h;
- 9 (j) subjecting the substrate of step i to
- 10 ELISA and comparing the results of said ELISA to ELISA
- 11 results from normal sera utilized as a control.

12 129. A process for the detection of antigens coded  
13 for by the pre-S gene in sera of HBV infected animals  
14 according to claim 128, wherein said substrate is  
15 polystyrene beads.

16 130. A process for the detection of antibodies to  
17 the pre-S region of hepatitis B virus comprising:

18 (a) adsorbing on a solid substrate,  
19 containing binding sites thereon, a peptide having an amino  
20 acid chain corresponding to at least six consecutive amino  
21 acids within the pre-S gene coded region of the envelope of  
22 HBV, said peptide free of an amino acid sequence  
23 corresponding to the naturally occurring envelope proteins  
24 of hepatitis B virus,

25 (b) contacting the substrate from step a  
26 with a material to saturate the binding sites thereon,

27 (c) washing the substrate from step b,

28  
29  
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1                   (d) contacting the substrate from step c  
2                   with a specimen comprising human sera to form a first  
3                   resultant mass,  
4                   (e) incubating the resultant mass of step d,  
5                   (f) washing the resultant mass of step e,  
6                   (g) adding radiolabeled antibodies to human  
7                   IGG or IGM to the resultant mass of step f to form a second  
8                   resultant mass,  
9                   (h) subjecting the second resultant mass of  
10                   step g to counting in a gamma counter,  
11                   (i) subjecting normal sera utilized as a  
12                   control to steps a to h and  
13                   (j) comparing the counts of steps h and i.  
14                   131. A process according to claim 130, wherein  
15                   said substrate is polystyrene beads.  
16                   132. A process for the detection of antibodies to  
17                   the pre-S region of hepatitis B virus comprising:  
18                   (a) adsorbing on a solid substrate,  
19                   containing binding sites thereon, a peptide having an amino  
20                   acid chain corresponding to at least six consecutive amino  
21                   acids within the pre-S gene coded region of the envelope of  
22                   HBV, said peptide free of an amino acid sequence  
23                   corresponding to the naturally occurring envelope proteins  
24                   of hepatitis B virus,  
25                   (b) contacting the substrate from step a  
26                   with a material to saturate the binding sites thereon,  
27                   (c) washing the substrate from step b,  
28  
29  
30

- 1 (d) contacting the substrate from step c  
2 with a specimen comprising human sera to form a first  
3 resultant mass,  
4 (e) incubating the resultant mass of step d,  
5 (f) washing the resultant mass of step e,  
6 (g) adding enzyme labeled antibodies to  
7 human IgG or IgM to the resultant mass of step f to form a  
8 second resultant mass,  
9 (h) subjecting the second resultant mass of  
10 step g to ELISA,  
11 (i) subjecting a normal sera utilized as a  
12 control to ELISA, and  
13 (j) comparing the ELISA results from steps h  
14 and i.  
15  
16 133. A process according to claim 132, wherein  
17 said substrate is polystyrene beads.  
18 134. A diagnostic test kit for detecting antigens  
19 coded for the pre-S gene of HBV in a test sample, comprising  
20 a. a solid substrate containing protein  
21 binding sites thereon, said substrate coated with antibodies  
22 to a peptide having an amino acid chain corresponding to at  
23 least six consecutive amino acids within the pre-S gene  
24 coded region of the envelope of HBV, said peptide free of an  
25 amino acid sequence corresponding to the naturally occurring  
26 proteins of HBV,  
27 b. a protein-containing solution to  
28 saturate protein binding sites on the solid substrate, and  
29 c. a given amount of radiolabeled or enzyme  
30 labelled antibody, said antibody to either the peptide or

1 HBsAg.

2 135. A diagnostic test kit for detecting  
3 antibodies to the pre-S region of hepatitis B virus in a  
4 test sample, comprising

5 a. a solid substrate containing protein  
6 binding sites thereon, said substrate having adsorbed  
7 thereon a peptide having an amino acid chain corresponding  
8 to at least six consecutive amino acids within the pre-S  
9 gene coded region of the envelope of HBV, said peptide free  
10 of an amino acid sequence corresponding to the naturally  
11 occurring proteins of HBV, the solid substrate exposed to  
12 a protein-containing solution to saturate protein binding  
13 sites on the solid substrate, and

14 b. a given amount of radiolabeled or enzyme  
15 labelled antibodies to human IgG or IgM.

16 136. A process for detecting antibodies to the  
17 pre-S region of hepatitis B virus in a sample which  
18 comprises:

19 a) contacting the sample with a solid substrate  
20 coated with a non-labelled peptide containing an amino acid  
21 chain corresponding to at least six consecutive amino acids  
22 within the pre-S gene coded region of the enveloping of HBV,  
23 the peptide free of an amino acid sequence corresponding to  
24 the naturally occurring envelope proteins of hepatitis B  
25 virus, incubating and washing said contacted sample;

26 b) contacting the incubated washed product  
27 obtained from step a above with a labelled peptide  
28 containing an amino acid chain corresponding to at least six  
29 consecutive amino acids within the pre-S gene coded region  
30

1 of the envelope of HBV, said peptide free of an amino acid  
2 sequence corresponding to the naturally occurring envelope  
3 protein of hepatitis B virus, incubating and washing the  
4 resultant mass; and

5 c) determining the extent of labelled peptide  
6 present in the resultant mass obtained by step b above.

7 137. A process according to claim 136, wherein  
8 a solid substrate is rendered substantially free of  
9 available protein binding sites.

10 138. A process according to claim 137, wherein  
11 the solid substrate is contacted with a protein binding site  
12 occupier.

13 139. A process according to claim 139, wherein  
14 the occupier is albumin.

15 140. A process for detecting antibodies to the  
16 pre-S region of hepatitis B virus in a sample comprising:

17 a) contacting the sample with a solid substrate  
18 coated with a non-labelled peptide containing an amino acid  
19 chain corresponding to at least six consecutive amino acids  
20 within the pre-S gene coded region of the envelope of HBV,  
21 the peptide free of an amino acid sequence corresponding to  
22 the naturally occurring envelope proteins of hepatitis B  
23 virus, incubating and washing said contacted sample;

24 b) contacting the incubated washed product  
25 obtained from step a above with labelled antibody to human  
26 or animal immunoglobulin product by contact with an  
27 immunogen comprising a peptide corresponding to at least six  
28 consecutive amino acids within the pre-S gene coded region  
29 of the envelope of HBV, said peptide immunogen free of an  
30

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1 amino acid sequence corresponding to the naturally occurring  
2 envelope proteins of hepatitis B virus, incubating and  
3 washing the contacted sample, and

4 c) determining the extent of labelled antibody  
5 present in the resultant mass of step b.

6 141. A process for detecting HBV or HBsAg in a  
7 sample comprising:

8 a) contacting a first portion of a composition  
9 containing an antibody produced by introducing into an  
10 animal or human an immunogen comprising a peptide  
11 corresponding to at least six consecutive amino acids within  
12 the pre-S gene coded region of the envelope of HBV, said  
13 peptide immunogen free of an amino acid sequence  
14 corresponding to the naturally occurring envelope proteins  
15 of hepatitis B virus with a mixture of said sample and said  
16 immunogen which has been labelled, incubating and washing  
17 said first protein;

18 b) contacting a second portion of said  
19 composition containing antibody with the same amount of said  
20 labelled immunogen in an antigen free control, incubating  
21 and washing said second portion;

22 c) adding the same amount of Staphylococci  
23 bearing protein A to each of the compositions of steps a and  
24 b above, incubating both of said compositions, centrifuging  
25 each of said compositions and separating liquid from the  
26 solids therein;

27 d) determining the extent of labelled immunogen  
28 in each of the resultant compositions from step c above, and

29 e) comparing the relative amount of labelled  
30

1 immunogen in each such that if the activity of the resultant  
2 composition containing the first portion is less than the  
3 activity for the resultant composition of the second  
4 portion, then the sample contains HBV or HBsAg.

5 142. A diagnostic test kit for detecting  
6 hepatitis B virus in sera comprising

7 a) a given amount of antibody to a peptide  
8 containing an amino acid chain corresponding to at least six  
9 consecutive amino acids within the pre-S gene coded region  
10 of the envelope of HBV, said peptide being free of an amino  
11 acid chain corresponding to the naturally occurring envelope  
12 proteins of hepatitis B virus, the antibody being bound to a  
13 solid support,

14 b) labelled antibody to the peptide or to  
15 hepatitis B virus.

16 143. A diagnostic test kit for detecting  
17 hepatitis B virus in sera according to claim 142, which  
18 further comprises a set of instructions for effecting an  
19 immunoassay wherein the effect of formation of an immune  
20 complex is revealed by said labelled antibody.

21 144. A diagnostic test kit for detecting  
22 hepatitis B virus in sera according to claim 143, wherein  
23 said antibody is insolubilized on a water insoluble solid  
24 support.

25 145. A diagnostic kit for detecting the presence  
26 of antibodies to hepatitis B virus comprising

27 a) a given amount of a peptide containing  
28 an amino acid chain corresponding to at least six  
29 consecutive amino acids within the pre-S gene coded region  
30

1 of the envelope of HBV, said peptide being free of an amino  
2 acid chain corresponding to the naturally occurring envelope  
3 proteins of hepatitis B virus,

4 b) labelled antibodies to human IgG or IgM.

5 146. A diagnostic kit for detecting the presence  
6 of antibodies to hepatitis B virus according to claim 145,  
7 which further comprises a set of instructions for effecting  
8 an immunoassay, wherein the extent of formation of an immune  
9 complex is revealed by said labelled antibodies.

10 147. A diagnostic test kit for detecting  
11 hepatitis B virus in sera according to claim 145, wherein  
12 said peptide is insolubilized upon a water insoluble solid  
13 support.

14 148. A process for predicting the outcome of  
15 hepatitis B infection which comprises carrying out an  
16 immunoassay on serum of a human to detect the presence of an  
17 antibody to an antigen coded for by the pre-S gene coded  
18 region of the envelope of hepatitis B virus employing the  
19 peptide immunogen of claim 1 at regular intervals and  
20 evaluating the data.

21 149. A process for determining if a human who has  
22 been vaccinated with a vaccine against hepatitis B has  
23 become immune to hepatitis B virus which comprises effecting  
24 a plurality of immunoassays of serum from such human to  
25 determine if there are antibodies in said serum to an  
26 antigen coded by the pre-S gene coded region of the envelope  
27 of hepatitis B virus employing the peptide immunogen of  
28 claim 1, said immunoassays being performed on serum taken  
29 from said human at different times.  
30

1                   150. A method for detecting the presence of  
2 hepatitis B virus infection comprising effecting quantative  
3 immunoassays on a serum sample taken from a human to  
4 determine the amount of antibodies present therein which are  
5 antibodies to an antigen coded by the pre-S gene coded  
6 region of the envelope of the hepatitis B virus employing  
7 the peptide immunogen of claim 1 and comparing the value  
8 with a known standard.

9                   151. A process for raising antibodies which  
10 comprises introducing into an animal the peptide immunogen  
11 of claim 1.

12                  152. In a process for synthesizing His and Trp  
13 containing peptides which includes the steps of

- 14                  a. linking a first amino acid containing an  
15 alpha-amino protecting group to a resin;  
16                  b. removal of said alpha-amino protecting group;  
17                  c. coupling a second amino acid containing an  
18 alpha-amino protecting group to said first amino acid;  
19                  d. repeating steps b and c by coupling further  
20 alpha-protected amino acids to produce a desired peptide  
21 wherein at least one of said amino acids is His  
22 and wherein at least one of said amino acids is Trp and the  
23                  e. cleaving the peptide from the resin and  
24 removing remaining protective groups to said first amino  
25 acids,  
26

27                  wherein the improvement comprises substituting an  
28 His(ImDNP) for said His, substituting a Trp(InFormyl) for  
29 said Trp, removing said DNP prior to cleavage and said  
30 removing of protective group, and removing said Formyl



1 during said cleavage and said removing of protective group.

2 153. A hepatitis B vaccine comprising  
3 a peptide containing an amino acid chain  
4 corresponding to at least six consecutive amino acids within  
5 the pre-S gene coded region of the envelope of HBV, said  
6 vaccine free of an amino acid sequence corresponding to the  
7 naturally occurring envelope proteins of hepatitis B virus,  
8 and

9 a physiologically acceptable diluent.

10 154. A hepatitis B vaccine according to claim 153,  
11 wherein said chain of amino acids is between sequence  
12 position pre-S 120 and pre-S 174.

13 155. A hepatitis B vaccine according to claim 154,  
14 wherein said chain of amino acids includes N-terminal  
15 methionine at sequence position pre-S 120.

16 156. A hepatitis B vaccine according to claim 153,  
17 wherein said chain of amino acids is between sequence  
18 position pre-S 1 and pre-S 120.

19 157. A hepatitis B vaccine according to claim 153,  
20 wherein said peptide contains a chain of at least 10 amino  
21 acids.

22 158. A hepatitis B vaccine according to claim 153,  
23 wherein said peptide contains a chain of at least 15 amino  
24 acids.

25 159. A hepatitis B vaccine according to claim 153,  
26 wherein said peptide contains a chain of at least 20 amino  
27 acids.

28 160. A hepatitis B vaccine according to claim 153,  
29 wherein said peptide contains a chain of at least 26 amino  
30

1 acids.

2 161. A hepatitis B vaccine according to claim 160,  
3 wherein said chain is between and including sequence  
4 positions pre-S 120 and pre-S 174.

5 162. A hepatitis B vaccine according to claim 161,  
6 wherein said chain includes N-terminal methionine at  
7 sequence position pre-S 120.

8 163. A hepatitis B vaccine according to claim 153,  
9 wherein said chain is between and including sequence  
10 position pre-S 15 and pre-S 120.

11 164. A hepatitis B vaccine according to claim 153,  
12 wherein said chain is between and including sequence  
13 position pre-S 15 and pre-S 55.

14 165. A hepatitis B vaccine according to claim 153,  
15 wherein said chain is between and including sequence  
16 position pre-S 90 and pre-S 120.

17 166. A hepatitis B vaccine according to claim 153,  
18 wherein said chain is between and including sequence  
19 position pre-S 10 and pre-S 40.

20 167. A hepatitis B vaccine according to claim 153,  
21 wherein said chain corresponds to amino acids in the ayw  
22 subtype of the pre-S region.

23 168. A hepatitis B vaccine according to claim 153,  
24 wherein said chain corresponds to amino acids in the adyw  
25 subtype of the pre-S region.

26 169. A hepatitis B vaccine according to claim 153,  
27 wherein said chain corresponds to amino acids in the adw2  
28 subtype of the pre-S region.  
29  
30

1           170. A hepatitis B vaccine according to claim 153,  
2 wherein said chain corresponds to amino acid in the adw  
3 subtype of the pre-S region.

4           171. A hepatitis B vaccine according to claim 153,  
5 wherein said chain corresponds to amino acids in the adr  
6 subtype of the pre-S region.

7           172. A hepatitis B vaccine according to claim 153,  
8 wherein said vaccine is free of any serum proteins.

9           173. A hepatitis B vaccine according to claim 153,  
10 wherein said chain is MQWNSTAFHQTLQDPRVRGLYLPAGG.

11           174. A hepatitis B vaccine according to claim 153,  
12 wherein said chain is MGTNLSVPNPLGFFPDHQLDP.

13           175. A hepatitis B vaccine according to claim 153,  
14 wherein said chain is PAFGANSNNPDWFNPNVKDDWP.

15           176. A hepatitis B vaccine according to claim 153,  
16 wherein said chain is PQAMQWNSTAFHQTLQDP.

17           177. A hepatitis B vaccine according to claim  
18 153, wherein said chain is PASTNRQSGRQPTPISPLRDSHP.

19           178. A hepatitis B vaccine according to claim 153,  
20 wherein said chain is PAPNIASHISSISARTGDP.

21           179. A hepatitis B vaccine according to claim  
22 153, wherein said chain is MGGWSSKPRKGMGTNLSVNP.

23           180. A hepatitis B vaccine according to claim 153,  
24 wherein said chain is PAFGANSNNPDWFNPNVKDDWP.

25           181. A hepatitis B vaccine according to claim 153,  
26 wherein said chain is QVGVGAFGPRLTPPHGG.

27           182. A hepatitis B vaccine according to claim 153,  
28 wherein said chain is MGGWSSKPRKG.  
29  
30

1                   183. A hepatitis B vaccine according to claim 153,  
2 wherein said chain is MGGWSSKPRQG.

3                   184. A hepatitis B vaccine according to claim  
4 153, wherein said vaccine is free of an amino acid sequence  
5 corresponding to the entire S gene coded region of the env  
6 gene product of hepatitis B virus.

7                   185. A hepatitis B vaccine according to claim  
8 153, wherein said peptide has no more than 100 amino acids.

9                   186. A hepatitis B vaccine according to claim  
10 153, wherein said peptide has no more than 40 amino acids.

11                   187. A hepatitis B vaccine according to claim  
12 153, wherein said peptide has no more than 30 amino acids.

13                   188. A hepatitis B vaccine according to claim  
14 153, wherein said peptide is capable of forming neutralizing  
15 antibodies to hepatitis B virus in a humans.

16                   189. A hepatitis B vaccine according to claim 153,  
17 wherein said peptide is linked to a carrier.

18                   190. A hepatitis B vaccine according to claim 189,  
19 wherein said peptide is covalently linked to a carrier.

20                   191. A hepatitis B vaccine according to claim  
21 190, wherein said peptide is covalently linked to a lipid  
22 vesicle carrier.

23                   192. A hepatitis B vaccine according to claim 191,  
24 wherein said lipid vesicle is stabilized by cross-linking.

25                   193. A hepatitis B vaccine according to claim  
26 153, wherein said chain is pre-S(120-145).

27                   194. A hepatitis B vaccine according to claim  
28 153, wherein said chain is pre-S(12-32).  
29  
30

1           195. A hepatitis B vaccine according to claim  
2           153, wherein said chain is pre-S(117-134).

3           196. A hepatitis B vaccine according to claim  
4           153, wherein said chain is pre-S(94-117).

5           197. A hepatitis B vaccine according to claim  
6           153, wherein said chain is pre-S(153-171).

7           198. A hepatitis B vaccine according to claim  
8           153, wherein said chain is pre-S(1-21).

9           199. A hepatitis B vaccine according to claim  
10          153, wherein said chain is pre-S(57-73).

11          200. A method of protecting a human against  
12          becoming infected with hepatitis B comprising administering  
13          to said human an effective dosage of a vaccine according to  
14          claim 153.

15          201. A method for detecting the presence of  
16          hepatitis B virus infection comprising effecting quantitative  
17          immunoassays on a serum sample taken from a human to  
18          determine the amount of antigens coded by the pre-S gene  
19          coded region of the envelope of the hepatitis B virus  
20          employing antibodies to the peptide immunogen of claim 1 and  
21          comparing the value with a known standard.  
22

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FIG. 1  
a b

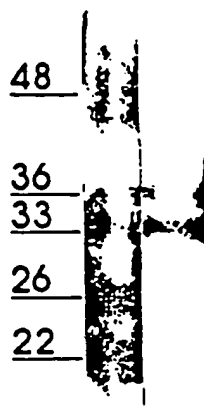
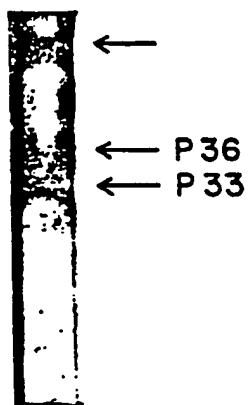


FIG. 6



**FIG. 2**

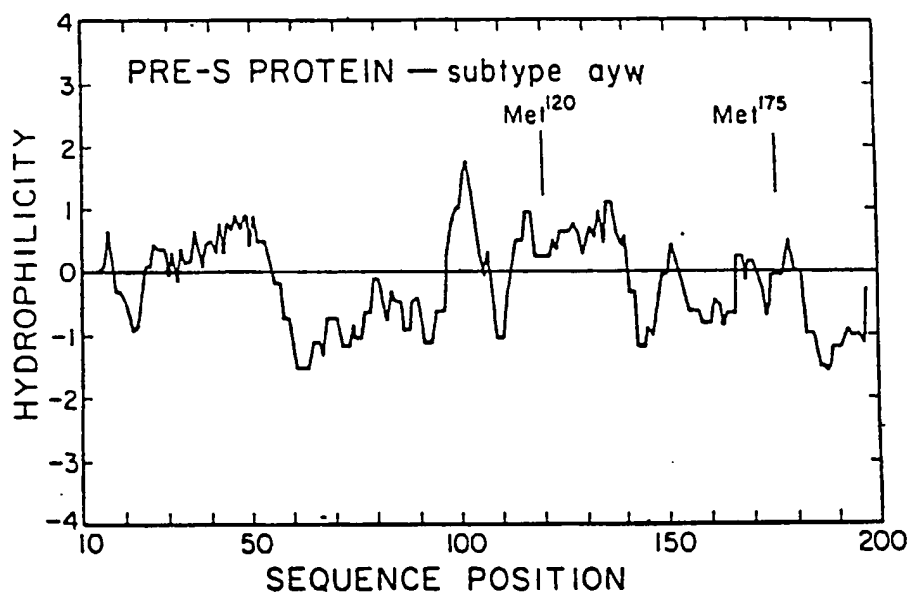
## Pre-S protein

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FIG. 3





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FIG. 4A

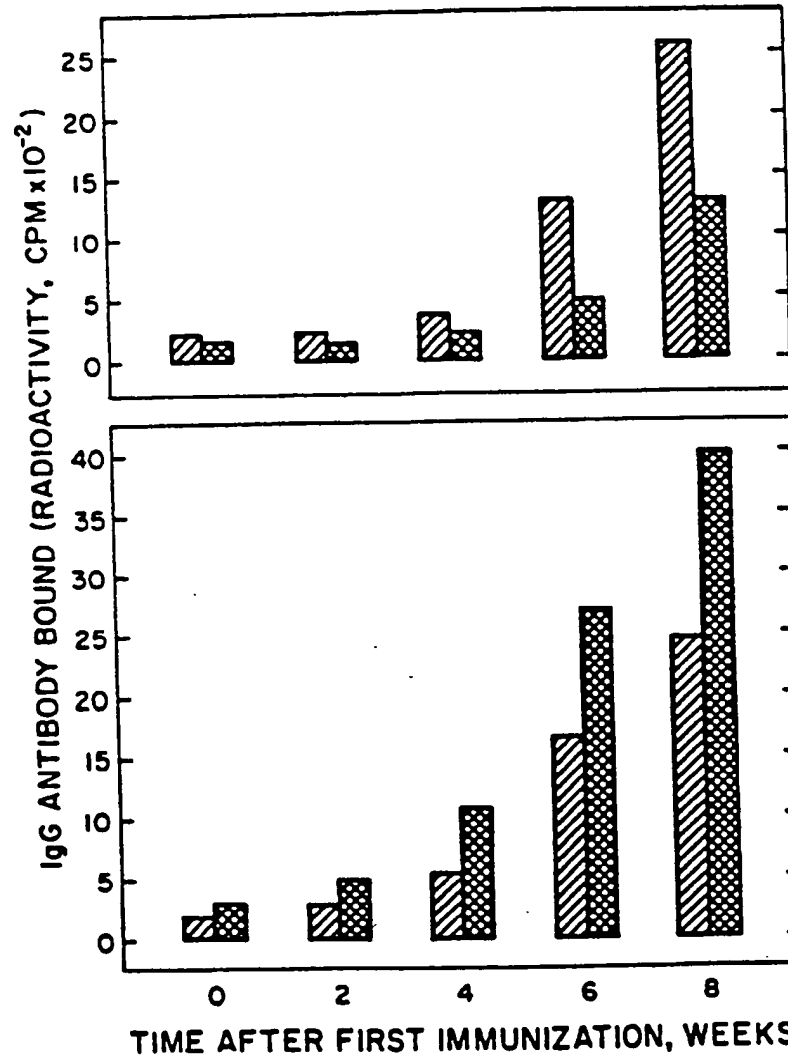
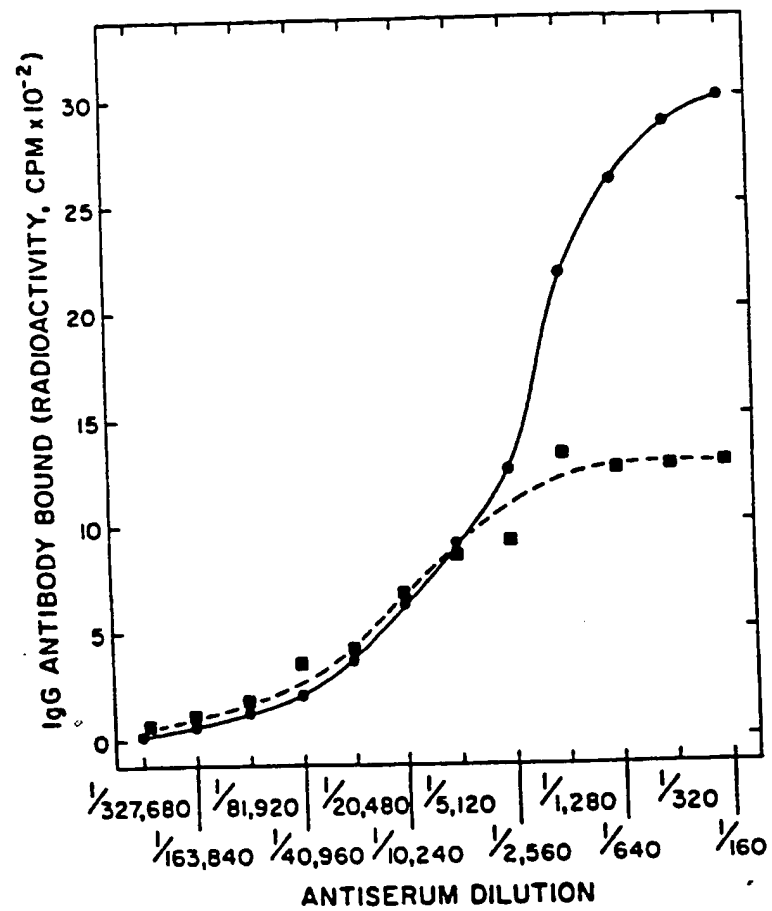


FIG. 4B

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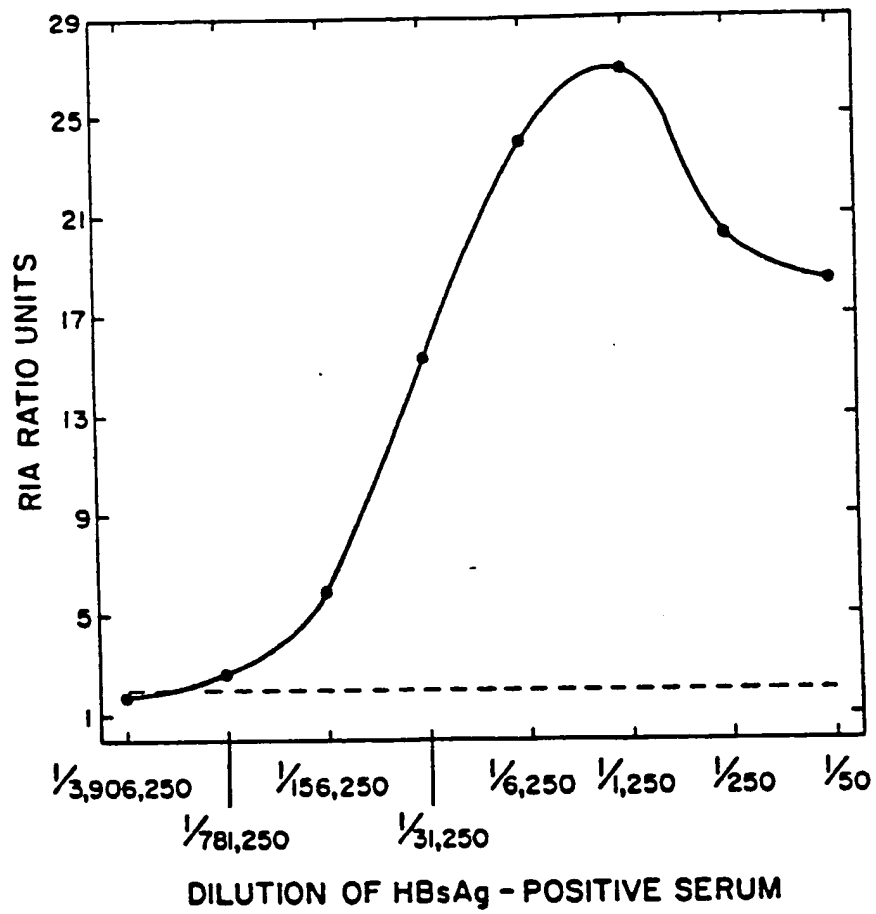
FIG. 5



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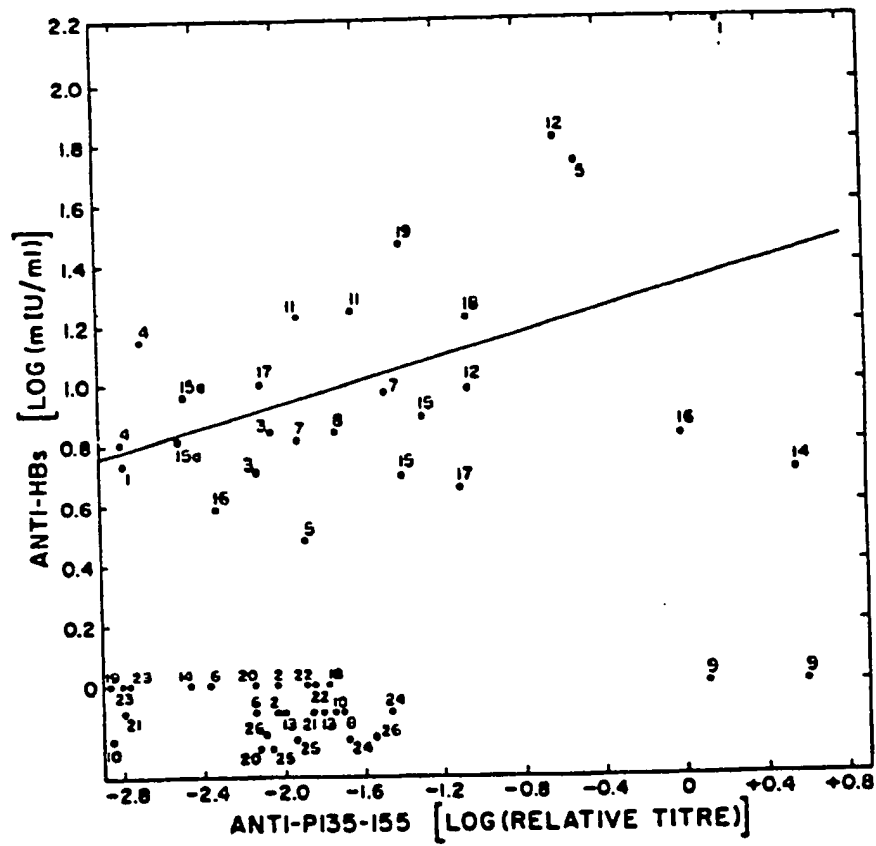
FIG. 7



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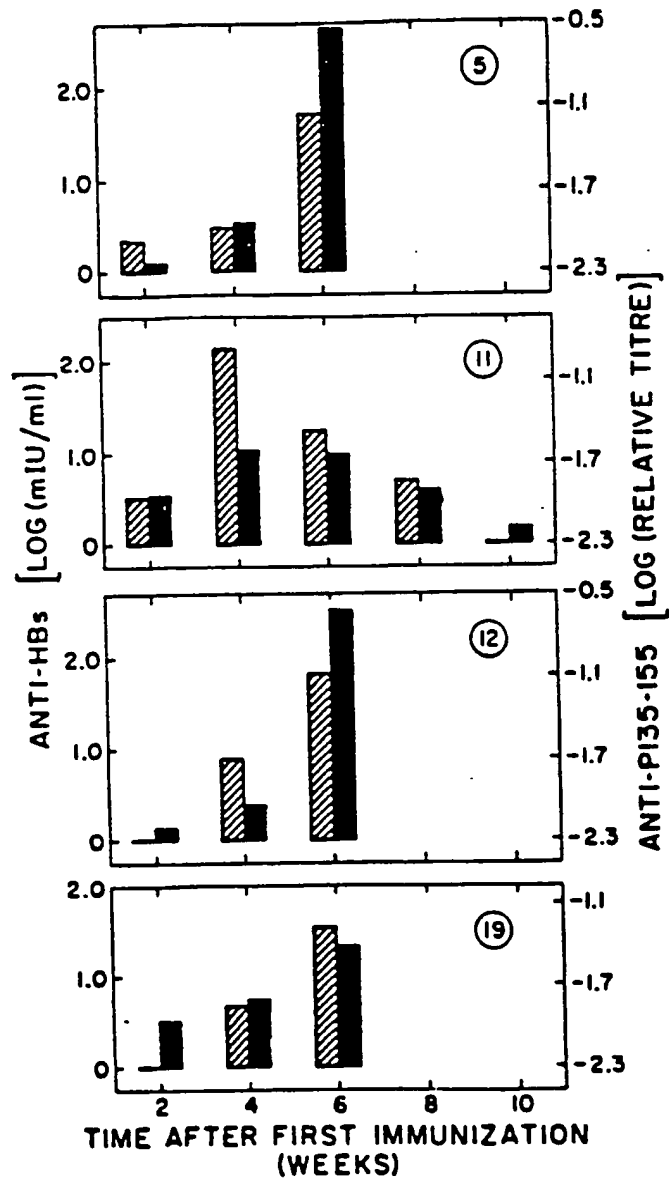
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FIG. 8



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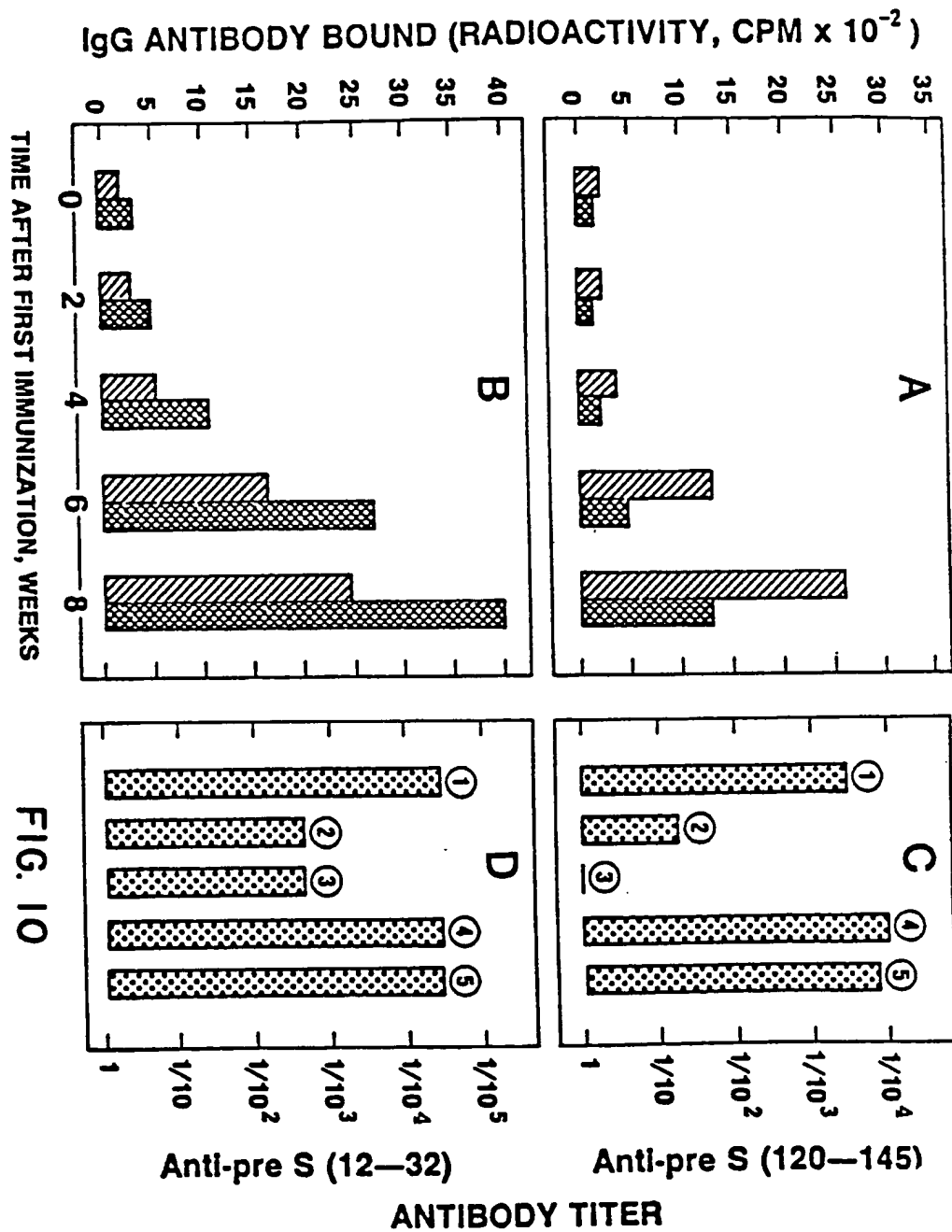


FIG. 10



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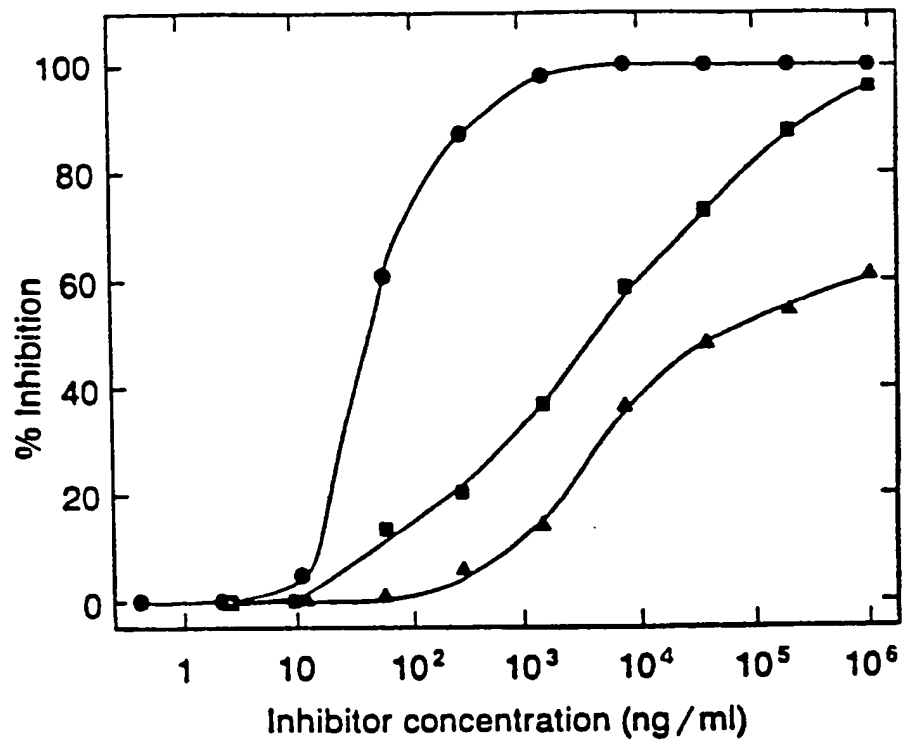


FIG. 12



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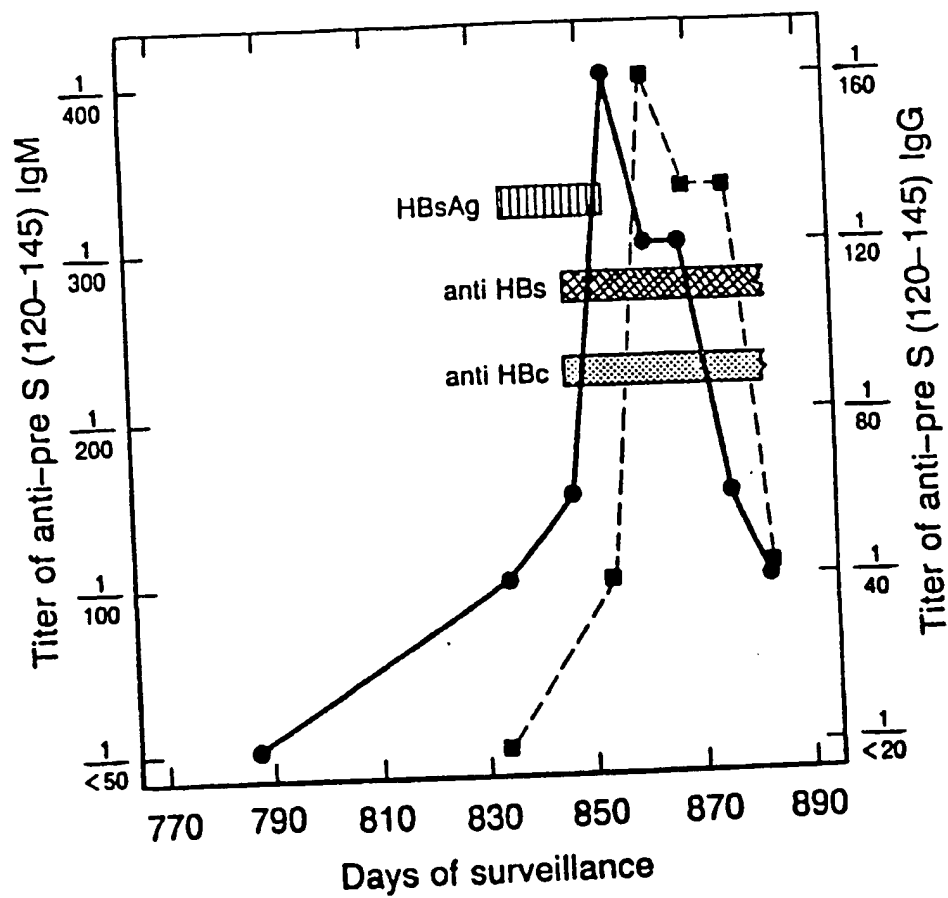
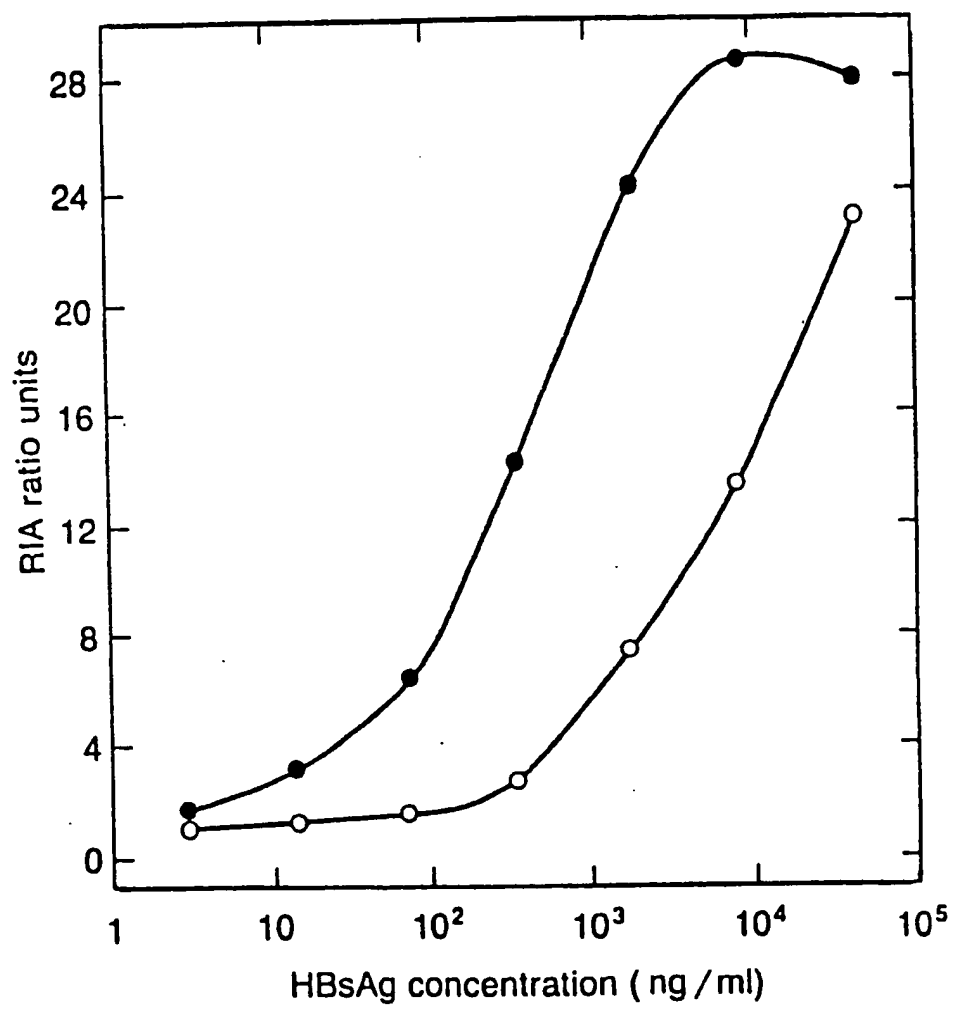


FIG. 13

**FIG. 15**